Norfolk Vanguard Offshore Wind Farm

Chapter 11

Fish and Shellfish Ecology

Environmental Statement

Volume 1

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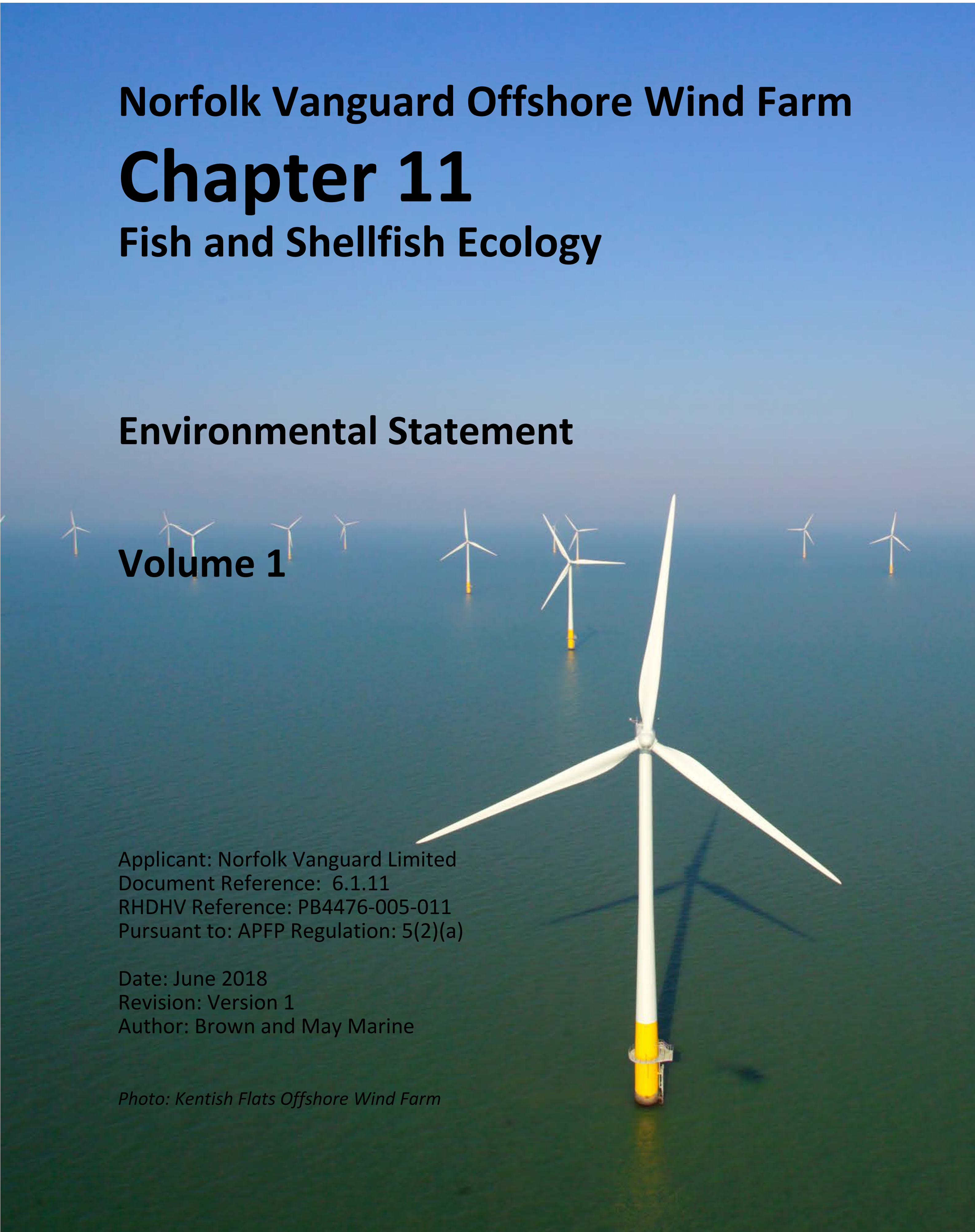

Photo: Kentish Flats Offshore Wind Farm

Environmental Impact Assessment
Environmental Statement

Document Reference: PB4476-005-011

June 2018

For and on behalf of Norfolk Vanguard Limited Approved by: Ruari Lean, Rebecca Sherwood Signed: [redacted] Date: 8th June

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Glossary

AC	Alternating current
B	Magnetic field
BAP	Biodiversity Action Plan
Cefas	Centre for Environment, Fisheries and Aquaculture Science
cm	centimetres
COWRIE	Collaborative Wind Research into the Environment
dB	Decibel
CHARM	Channel Habitat Atlas for Marine Resource Management
COWRIE	Collaborative Offshore Wind Research into the Environment
CPA	Coast Protection Act
CPUE	Catch Per Unit Effort
DC	Direct current
DEFRA	Department of Environment, Food and Rural Affairs
DTI	Department of Trade and Industry
E	Electric field
EIA	Environmental Impact Assessment
EIFCA	Eastern Inshore Fisheries and Conservation Authority
EMF	Electromagnetic field
EPP	Evidence Plan Process
ETG	Expert Topic Group
FEPA	Food and Environment Protection Act
HVAC	High voltage alternating current
HVDC	High voltage direct current
Hz	Hertz
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IUCN	International Union for the Conservation of Nature
IMARES	Institute of Marine Resources and Ecosystem Studies, the Netherlands
kJ	Kilojoule
km	Kilometre
km^2	Kilometre squared
kV	Kilovolt
m	Metre
m^2	Metre squared
m^3	Metre cubed
MarLIN	Marine Life Information Network
MCEU	Marine Consents and Environment Unit
mg/l	Milligram per litre
MMO	Marine Management Organisation
MW	Megawatt

µT	Microtesla
NPS	National Policy Statement
O&M	Operation and Maintenance
OSPAR	Oslo Paris Convention
OWF	Offshore wind farm
PEIR	Preliminary Environmental Information Report
PSA	Particle Size Analysis
SEL_{cum}	Cumulative Sound Exposure Level
SPL_{peak}	Peak Sound Pressure Level
SSC	Suspended Sediment Concentration
TTS	Temporary Threshold Shift

Terminology

Array cables	Cables which link the wind turbine generators and the offshore electrical platform.
Beam trawl	A trawl net whose lateral spread during trawling is maintained by a beam across its mouth.
Benthic	Relating to, or occurring at the sea bottom.
Bioelectric	Relating to electricity or electrical phenomena produced within living organisms.
Bony fish	Any of a major taxon (class Osteichthyes or superclass Teleostomi) comprising fishes with a bony rather than a cartilaginous skeleton.
Clupeid	Any of various fishes of the family Clupeidae, which includes the herrings, sprats, sardines and shads.
Crustacean	An arthropod of the large, mainly aquatic group Crustacea, such as a crab, lobster, shrimp, or barnacle.
Demersal	Living on or near the seabed.
Diadromous	Migrating between fresh and salt water.
Elasmobranch	Any cartilaginous fish of the subclass Elasmobranchii which includes the sharks, rays and skates.
Electro-receptive	Ability to perceive electrical stimuli.
Epibenthic	Relative to the flora and fauna living on the surface of the sea bottom.
Gadoid	A bony fish of an order (Gadiformes) that comprises the cods, hakes, and their relatives.
Geomagnetic field	The Earth's magnetic field.
Gravid	Carrying eggs or young
Interconnector cables	Buried offshore cables which link the offshore electrical platforms.
Landfall	Where the offshore cables come ashore at Happisburgh South.
Mollusc	An invertebrate of a large phylum which includes snails, slugs, mussels, and octopuses. They have a soft unsegmented body and live in aquatic or damp habitats, and most kinds have an external calcareous shell.
Offshore accommodation	A fixed structure (if required) providing accommodation for offshore personnel.

platform	An accommodation vessel may be used instead.
Offshore cable corridor	The corridor of seabed from the Norfolk Vanguard OWF sites to the landfall site within which the offshore export cables will be located.
Offshore electrical platform	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore.
Offshore export cables	The cables which bring electricity from the offshore electrical platform to the landfall.
Offshore project area	The overall area of Norfolk Vanguard East, Norfolk Vanguard West and the offshore cable corridor.
Otter trawl	A trawl net fitted with two 'otter' boards which maintain the horizontal opening of the net.
Ovigerous	Carrying or bearing eggs.
Pelagic	Living in the water column.
Piscivorous	Feeding on fish.
Safety zone	A marine zone outlined for the purposes of safety around a possibly hazardous installation or works / construction area under the Energy Act 2004.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
Swim bladder	A gas-filled sac present in the body of many bony fish, used to maintain and control buoyancy.
The Applicant	Norfolk Vanguard Limited.
The OWF sites	The two distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West.
The project	Norfolk Vanguard Offshore Wind Farm, including the onshore and offshore infrastructure.

11 FISH AND SHELLFISH ECOLOGY

11.1 Introduction

1. This chapter has been prepared by Brown and May Marine Limited (BMM) and presents the results of the Environmental Statement (ES) of the proposed Norfolk Vanguard development ("the project") on fish and shellfish ecology. The areas of the project relevant to this assessment are the Offshore Wind Farm (OWF) sites (Norfolk Vanguard East (NV East) and Norfolk Vanguard West (NV West)), and the offshore cable corridor. Collectively these project components are referred to as 'the offshore project area'.

2. The ES assesses potential impacts during the construction, decommissioning, and operation and maintenance (O&M) phases of the project, in addition to those which may arise cumulatively with other offshore renewable developments and marine developments and activities.

3. The characterisation of the existing environment and impact assessment have been derived using data and information from a number of sources, including the scientific literature, fisheries statistical datasets, and fish and shellfish surveys undertaken within the former East Anglia Zone. Consultation has been undertaken with statutory and non-statutory stakeholders including the Marine Management Organisation (MMO), Centre for Environment, Fisheries and Aquaculture Science (Cefas), Eastern Inshore Fisheries and Conservation Authority (EIFCA) and commercial fisheries organisations.

4. Impacts assessed on fish and shellfish ecology have potential inter-relationships with the following offshore environment topics:

- Chapter 10 Benthic and Intertidal Ecology;
- Chapter 12 Marine Mammal Ecology;
- Chapter 13 Offshore Ornithology; and
- Chapter 14 Commercial Fisheries.

11.2 Legislation, Guidance and Policy

5. The assessment of potential impacts on fish and shellfish ecology has been undertaken with specific reference to the relevant National Policy Statement (NPS). Those relevant to the project are as follows:

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC, 2011); and
- NPS for Renewable Energy Infrastructure (EN-3), July 2011.

6. The Overarching NPS for Energy (EN-1) sets out the Government's policy for delivery of major energy infrastructure, with generic considerations which are further considered in the technology-specific NPSs such as the NPS for Renewable Energy Infrastructure (EN-3). Table 11.1 summarises guidance relevant to the ES in respect of fish and shellfish ecology from EN-3 as well as providing the sections in this ES where each is addressed.

Table 11.1 NPS assessment requirements

NPS Requirement	NPS EN3 Reference	ES Section Reference
Effects of offshore wind farms can include temporary disturbance during the construction phase (including underwater noise) and ongoing disturbance during the operational phase and direct loss of habitat. Adverse effects can be on spawning, overwintering, nursery and feeding grounds and migratory pathways in the marine area. However, the presence of wind turbines can also have positive benefits to ecology and biodiversity.	Section 2.6.63	Section 11.7.
Assessment of offshore ecology and biodiversity should be undertaken by the applicant for all stages of the lifespan of the proposed offshore wind farm and in accordance with the appropriate policy for offshore wind farm EIAs (EN-3; Paragraph 2.6.64).	Section 2.6.64	Section 11.7.
Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate	Section 2.6.65	Section 6.
Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore wind farm should be referred to where appropriate	Section 2.6.66	Section 11.7.5.
The assessment should include the potential for the scheme to have both positive and negative impacts on marine ecology and biodiversity	Section 2.6.67	Section 11.4.1.
There is the potential for the construction and decommissioning phases, including activities occurring both above and below the sea bed, to interact with seabed sediments and therefore have the potential to impact fish communities, migration routes, spawning activities and nursery areas of particular species. In addition, there are potential noise impacts, which could affect fish during construction and decommissioning and to a lesser extent during operation.	Section 2.6.73	Section 11.7.
The applicant should identify fish species that are the most likely receptors of impacts with respect to: • spawning grounds; • nursery grounds; • feeding grounds; • over-wintering areas for crustaceans; and • migration routes.	Section 2.6.74	Section 11.6.10.
Where it is proposed that mitigation measures of the type set out in paragraph 2.6.76 below are applied to offshore export cables to reduce electromagnetic fields (EMF) the residual effects of EMF on sensitive species from cable infrastructure during operation are not likely to be significant.	Section 2.6.75	Section 11.7.5.4.

NPS Requirement	NPS EN3 Reference	ES Section Reference
Once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement		
EMF during operation may be mitigated by use of armoured cable for inter-array and export cables that should be buried at a sufficient depth. Some research has shown that where cables are buried at depths greater than 1.5m below the sea bed impacts are likely to be negligible. However, sufficient depth to mitigate impacts will depend on the geology of the sea bed.	Section 2.6.76	Section 11.7.5.4.
During construction, 24 hour working practices may be employed so that the overall construction programme and the potential for impacts to fish communities is reduced in overall time.	Section 2.6.77	Section 11.7.1.
The construction and operation of offshore wind farms can have both positive and negative effects on fish and shellfish stocks.	Section 2.6.122	Section 11.4.1.

7. In addition to NPS guidance, the following documents have been used to inform the fish and shellfish ecology assessment:

- Cefas, Marine Consents and Environment Unit (MCEU), Department for Environment, Food and Rural Affairs (DEFRA) and Department of Trade and Industry (DTI) (2004) Offshore Wind Farms - Guidance note for Environmental Impact Assessment In respect of the Food and Environment Protection Act (FEPA) and CPA requirements, Version 2;
- Cefas (2012) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Contract report: ME5403, May 2012;
- Guidelines for ecological impact assessment in Britain and Ireland: Marine and Coastal. IEEM (2010);
- Sound Exposure Guidelines for Fishes and Sea Turtles Monitoring (Popper *et al.*, 2014);
- Renewable UK (2013) Cumulative Impact Assessment Guidelines Guiding Principles for Cumulative Impacts Assessment in Offshore Wind Farms;
- Marine Licensing requirements (replacing Section 5 Part II of the FEPA 1985 and Section 34 of the Coast Protection Act (CPA) 1949);
- Strategic Review of Offshore Windfarm Monitoring Data Associated with FEPA Licence Conditions (Cefas, 2010);
- East Inshore and East Offshore Marine Plans (MMO and Department for Environment, Food and Rural Affairs, 2014);

- Blyth-Skyrme, R.E. (2010) Options and opportunities for marine fisheries mitigation associated with wind farms. Final report for Collaborative Offshore Wind Research into the Environment contract FISHMITIG09. COWRIE Ltd, London; and
- Norfolk Vanguard Scoping Opinion (The Planning Inspectorate, 2016).

11.3 Consultation

8. Consultation is a key part of the Development Consent Order (DCO) application process. To date, consultation regarding fish and shellfish ecology has been conducted through an Expert Topic Group (ETG) meeting held in 2017, the Scoping Report (Royal HaskoningDHV, 2016) and on the Preliminary Environmental Information Report (Norfolk Vanguard Limited, 2017). ETG minutes are presented within Appendix 9.16 of the Consultation Report (document 5.1).

9. Consultation undertaken to inform this ES is listed in Table 11.2.

Table 11.2 Consultation responses

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
MMO	November 2016 Norfolk Vanguard Scoping Opinion (The Planning Inspectorate, 2016)	Overall the key species of importance and potential impacts to fish have been correctly identified.	Key receptors included for assessment are in line with those identified during the scoping exercise as requiring assessment and are outlined in section 11.6.10.
MMO	November 2016 Norfolk Vanguard Scoping Opinion (The Planning Inspectorate, 2016)	The data gathered points to the presence of appropriate habitat for sand eels, while the mapped spawning areas/nursey grounds for sand eels point to the presence of the species within the area. An assessment of the effects on sand eel including its habitats is therefore required within the ES. We recommend that the aggregate industry sand eel habitat assessment (Marine Space, 2013) criteria be considered as an approach during the Environmental Impact Assessment (EIA) to assess habitat significance.	The potential impacts of the project on sandeels have been assessed throughout the impact assessment within this document taking account of habitat significance. This has been assessed taking account of the distribution of spawning and nursery grounds of the species, information provided in Jensen *et al.* (2011) on key sandeel grounds in the North Sea, as well as analysis of sediment data to define potential sandeel habitat suitability following Marine Space (2013) approach (see Figure 11.10, Figure 11.20, Figure 11.21, Figure 11.22 and

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
			Appendix 11.1).
MMO	November 2016 Norfolk Vanguard Scoping Opinion (The Planning Inspectorate, 2016)	We recommend that any fisheries data taken from previous surveys that is used in the EIA includes all relevant information such as; dates and times of surveys, locations, gears used, mesh size, duration of tow/soak times. Any limitations of the data sources used should be presented in the ES.	Detailed information on survey locations, methods, dates and times is given in Appendix 11.1, including full survey results. Information on the limitations and sensitivities of the data sources used is provided in Appendix 11.1.
MMO	November 2016 Norfolk Vanguard Scoping Opinion (The Planning Inspectorate, 2016)	For the ES, we recommend a longer time series of data (e.g. up to ten years' worth of fisheries landings data) is used rather than the seven years proposed, to be consistent with applications of a similar nature. Requests for additional data can be submitted to the MMO for consideration. The ES should explain how landing weights have been calculated and we recommend showing the average landed weights broken down by International Council for Exploration of the Sea (ICES) rectangle. This will show any variation in abundance per rectangle for each species.	Average landings weight by species and ICES rectangle for a 10 year period (2007 -2016) have been analysed to inform this chapter (section 11.6.3 and Appendix 11.1**)**.
MMO	November 2016 Norfolk Vanguard Scoping Opinion (The Planning Inspectorate, 2016)	Table 2.13 (in the Scoping Opinion) uses ICES data to establish the average catch per unit effort per hour for individuals for species recorded in International Bottom Trawl Surveys (IBTS) within the ICES. Having reviewed the table, we believe that the data for both greater sand eel and Raitt's sand eel may be incorrect. For example, we have looked at ICES' IBTS data for 2011-2016 for sand eels and the largest catch per unit effort shown in the number per hour is 6.21 for greater sand eel in rectangle 34F2 in Quarter 3 of 2015. This will need to be corrected in the ES, and the MMO will engage with the applicant through the evidence plan process and provide relevant advice as to the accuracy and appropriateness of data.	Updated analysis of catch per unit effort data derived from the results of IBTS has been used to inform the assessment. The results are summarised in section 11.6.3 and provided in full in Appendix 11.1.

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
MMO	November 2016 Norfolk Vanguard Scoping Opinion (The Planning Inspectorate, 2016)	The MMO would also recommend that the International Herring Larval Survey (IHLS) data is reviewed and considered to determine if any potential underwater noise could impact herring. The extent to which herring larvae may be impacted by sediment plumes for example, should also be considered.	Results of the IHLS for the period 2007 to 2016 have been analysed (Figure 11.13-Figure 11.15) and used to inform the assessment of the potential impact of the project on herring (section 11.7.4.2- increased suspended sediment concentrations (SSCs) and sediment deposition; and section 11.7.4.3 - underwater noise).
Cefas	16th February 2017 Evidence Plan Process Meeting	Sea bass are under special protection measures this should be recognised in EIA. Cod have also been raised as a sensitive species (and were a concern for East Anglia ONE).	Both sea bass and cod have been included as key receptors (section 11.6.10) and have been considered throughout the impact assessment (section 11.7).
Cefas	16th February 2017 Evidence Plan Process Meeting	Cefas recommended sources for noise sensitivities to be used and the correct approach to modelling of piling impacts.	Cefas recommendations on the approach to the underwater noise modelling have been followed (section 11.7.4.3).
Cefas	16th February 2017 Evidence Plan Process Meeting	Will impacts to crab larvae be considered? This has been suggested by a local fisherman.	Due consideration has been given to the potential impacts of the project on life stages of limited mobility such as eggs and larvae throughout the impact assessment (section 11.7).
Cefas	16th February 2017 Evidence Plan Process Meeting	Sandeel will need to be considered. Monitoring at an offshore windfarm recently did not provide very positive results with regard to sandeel population recovery however this has been attributed to poorly designed surveys.	Due consideration has been given to the potential impacts of the project on sandeels throughout the impact assessment (section 11.7).
Cefas	16th February 2017 Evidence Plan Process Meeting	EMF should be considered for spurdog subject to cable burial depth.	Due consideration has been given to the potential impact of electromagnetic fields (EMFs) on elasmobranches (section 11.7.5.4), including shark species such as spurdog.
Cefas	16th February 2017 Evidence Plan Process	Impacts of increased suspended sediment on whelk should be considered.	Whelks, together with other relevant shellfish species, have been considered for assessment

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
	Meeting		of the impact of increased suspended sediment (section 11.7.4.2).
Eastern Inshore Fisheries Conservation Authority (IFCA)	December 2017 PEIR Response	Vattenfall should note that Eastern IFCA are seeking small-scale fishing closures (via a byelaw) to protect sensitive features within the inshore section (within six nautical miles of the shore) of the SCI. These closures are yet to be finalised, but any works in this area will need to proactively take into consideration up-to-date closures and the latest available information on the location of sensitive species and habitats. Eastern IFCA will ensure that any changes to existing fishery closures are duly publicised.	Noted.
Eastern IFCA	December 2017 PEIR Response	Sandeels rely on sandbanks and other sandy substrata similar to those found in the Haisborough, Hammond and Winterton SCI (Ellis et al., 2012). There is a potential pathway for the species to be impacted by the construction and operational work, as well as by the habitat loss associated with unburied, protected cable, however the PEIR has identified these as not significant. This should be further considered to address the cumulative impacts of the project on sandeels with other plans and projects in the Southern North Sea.	Consideration has been given to the potential impacts of the construction and operation phases of the project on sandeels (section 11.7.4 and section 11.7.5). The assessment carried out in respect of permanent loss of habitat takes account of the potential habitat loss as a result of the footprint of the project, including areas of unburied cable where protection may be required (section 11.7.5.1). An assessment of the potential cumulative impacts of the project on sandeels, and other fish and shellfish receptors, in conjunction with other developments in the Southern North Sea, has been undertaken and is presented in section 11.8. All potential impacts assessed for the project alone have also been considered for assessment of cumulative impacts
Eastern IFCA	December 2017 PEIR Response	Eastern IFCA would like to thank Vattenfall for taking into consideration the concerns of the Authority and other nature conservation bodies regarding running the cable route	Noted.

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
		through the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ), and for avoiding it in the finalised cable corridor. The Cromer Shoal Chalk Beds MCZ protects a range of seabed habitats, including subtidal chalk reefs, and peat and clay exposures, which provide important habitat and nursery areas for a variety of marine species, including commercially important fish and shellfish species	
Eastern IFCA	December 2017 PEIR Response	Many coastal habitats provide important spawning and nursery areas for a variety of marine species. Any disturbance to these habitats has the potential to negatively affect these populations. The inshore areas of the cable corridor identified, are understood to support nursery grounds for thornback ray, herring, cod, whiting, mackerel, plaice and sole. Furthermore, the area supports spawning grounds for herring, sole and sandeels (Ellis et al., 2012) – an important prey of the harbour porpoise, which is protected within the Southern North Sea cSAC.	Consideration has been given in this assessment to fish species with known spawning and nursey grounds in areas relevant to the project (Table 11.8 and Table 11.10). Fish species which are of importance as prey to marine mammals, including herring, sole and sandeels have been considered in the impact assessment within this chapter (Table 11.10). Potential impacts of the project on marine mammals are discussed in Chapter 12 Marine Mammals and in the Information to Support the Habitats Regulations Assessment (HRA) Report (document reference 5.3).
Eastern IFCA	December 2017 PEIR Response	Sandeels depend on the presence of adequate sandy substratum in which they burrow, and are demersal spawners that lay eggs on the seabed. Physical disturbance or loss of the seabed associated with the construction phase of the project could therefore have damaging impacts on this species. [Despite the conclusion that this impact will not be significant], we think the effects of offshore wind construction on fish and shellfish spawning and nursery grounds should be considered at a regional scale.	The regional distribution of sandeels has been given consideration both, for assessment of potential impacts of the project alone and cumulatively with other developments (Section 11.7.4, Section 11.7.5 and Section 11.8). Similarly, consideration has been given to the regional distribution of spawning and nursery grounds of relevant species for assessment of potential impacts of the project alone and cumulatively with other projects (Section 11.7.4,

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
			Section 11.7.5 and Section 11.8).
Eastern IFCA	December 2017 PEIR Response	Although the best available information (Coull et al., 1998; Jensen et al., 2011; Ellis et al., 2012) shows extensive spawning grounds for many species, Eastern IFCA is concerned about the scale of offshore activities (particularly aggregate extraction and offshore wind farm construction) in the Southern North Sea because of cumulative effects these could have on seabed habitats. Whilst we appreciate the difficulty in studying potential wide-scale impacts, we consider the issue does warrant further consideration.	Cumulative impacts in relation to fish and shellfish species are assessed in Section 11.8. Potential cumulative impacts on seabed habitats are discussed in Chapter 10, Benthic and Intertidal Ecology.
Eastern IFCA	December 2017 PEIR Response	Eastern IFCA maintains concerns about the potential for electromagnetic fields (EMF) from marine electricity cables affecting fish species, especially elasmobranchs (sharks, skates and rays) that are the most widespread electrosensitive fish group of UK coastal waters (CMACS, 2003). This is an increasing concern as the number of offshore energy development (and therefore marine electricity cables) increases – therefore cumulative effects of multiple developments must be considered. Currently there is uncertainty over whether EMF from cables does have an impact on receptive species. We suggest that the environmental impact assessment must present the latest understanding of this issue, and if appropriate, precautionary mitigation must be applied (e.g. use of high-permeability materials for armouring cables) to minimise impacts.	The assessment of the potential impact of electromagnetic fields (EMFs) on fish and shellfish species is based on the worst case scenario identified for the project (Section 11.7.5.4.4 and Table 11.11). In the context of the assessment of EMFs, it is important to note that from the results of other post-consent monitoring conducted to date, there is no evidence to suggest that EMFs pose a significant threat to elasmobranchs at the site or population level, and little uncertainty remains (MMO, 2014) (see paragraph 277). Consideration has been given in the cumulative assessment to the potential impact of EMFs associated with the project and other developments in the wider area on sensitive receptors (section 11.8). As described in Section 11.7.1, cables will be buried where possible to a minimum depth of 1m and protected where cable burial is not feasible.

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
MMO	December 2017 PEIR Response	With regard to fisheries impacts, the MMO concludes that the PEIR is generally well structured and provides a comprehensive preliminary consideration of the fish resources, feeding, spawning and nursery grounds with regard to the development of the Norfolk Vanguard Offshore Windfarm. Species of concern have been correctly identified along with potential impacts. The key species which were identified for inclusion in the assessment (Seabass, Cod, Spurdog and Sandeels have all been discussed within the PEIR).	The fish and shellfish species taken forward for assessment in the ES are as previously identified in the PEIR and include amongst other, seabass, cod, spurdog and sandeels (Table 11.10).
MMO	December 2017 PEIR Response	With regard to underwater noise impacts for fish species, piling, seabed preparation, rock dumping, cable installation and increased vessel traffic have all been identified as potential sources of underwater noise during construction. Although piling will produce the highest level of underwater noise, potential effects on fish receptors from other noise-generating activities should still be explored in the assessment including different phases such as operational and associated peripheral activities such as boulder clearance and UXO which have not been fully assessed.	The assessment of potential impacts associated with noise during construction has taken account of piling and other noise generating activities (cable installation and vessels noise). With regards to the operation phase, consideration has been given to noise impacts associated with the operational turbines and vessel noise. In addition, peripheral activities such as UXO clearance have also been included for assessment.
MMO	December 2017 PEIR Response	Generally, the timeliness of the data presented in the PEIR is appropriate as 10 years of MMO landings data, IBTS and International Herring Larval Surveys (IHLS) data has been included. However, the UK landings data presented were only obtained from the MMO for years up until 2015. Ideally 2016 landings data should also be included in the PEIR or Environmental Statement, which would ensure that the most current data was presented. The MMO recognises that the 2016 data may have been unavailable at the time the report was written. Please include this data to inform the EIA.	At the time of writing the PEIR, MMO landings data for the year 2016 were not available. These data have been released since and have been used to inform the ES chapter (See Appendix 11.1 Fish and Shellfish Ecology Technical Report).
MMO	December 2017 PEIR Response	It is also noted that Figure 11.60 illustrates VMS fishing intensity of the Danish sandeel fleet and that the data presented are from four years	The most up to date, available Danish sandeel VMS data (2011-2015) has been included

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
		between 2009-2013, and consequently does not include data from 2014 onwards. If more recent data is available this should be used to inform the EIA.	in this chapter (Figure 11.22) and in Appendix 11.1. This is in line with the data presented in Chapter 14 Commercial Fisheries.
MMO	December 2017 PEIR Response	Similarly, Appendix M states that as of 15/04/2016, Dutch VMS, Belgium landings/VMS, German Landings/VMS and Danish Landings/VMs are not included in the assessment, presumably as with the landings data. If this data is available it should be used to inform the final EIA.	Appendix M does not exist for this chapter, however details on landings are discussed below. An exhaustive analysis of available fisheries data (including VMS and landings statistics) is provided in Chapter 14 Commercial Fisheries for relevant fleets. Whilst consideration is given in this chapter to species of commercial importance, it is outside of the scope of this assessment to provide a detailed analysis of fishing activity. The most up to date available landings data for the UK and the principal non-UK fleets active in the area have however been included in Appendix 11.1 (Fish and Shellfish Technical Report). These data are provided with the aim of identifying key species of commercial importance in the area relevant to the project. Additionally, in the particular case of sandeels, given the patchy nature of their distribution, Danish VMS data for the sandeel fishery has been included in the chapter and used to inform the assessment.
MMO	December 2017 PEIR Response	The MMO notes that the IHLS 2016 data for the Central North Sea (CNS) is missing from Figure 11.15. This should be provided in the EIA if available. The MMO recognises that this may have been unavailable at the time of writing the report, though the Southern North Sea data is presented.	Figure 11.15 has been amended and IHLS data for the Central North Sea area is now included.

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
MMO	December 2017 PEIR Response	The MMO notes that paragraph 182 of the fish and shellfish technical report states that 'Cefas are currently of the opinion that smoothhounds and starry smoothhounds can be considered the same species and are not distinguishable by external physiological features (pers comm. J. Ellis, M. Etherton, Cefas 2013)'. Please note that Cefas's opinion is supported by peer-reviewed literature (Farrell et al., 2009).	Noted. Reference to Farrell et al., 2009 has now been made in Appendix 11.1 Fish and Shellfish Ecology Technical Report in respect of smoothound species.
MMO	December 2017 PEIR Response	Paragraph 205 states that there are no known Allis shad spawning sites in the UK. The applicant should be aware that a recently-confirmed spawning site has been found in the Tamar Estuary (Plymouth Sound and Estuaries cSAC) however, this is not relevant to the project.	Noted. Appendix 11.1 Fish and Shellfish Ecology Technical Report has been updated to include reference to the recently confirmed spawning site for Allis shad in the Tamar Estuary area.
MMO	December 2017 PEIR Response	With regard to shellfish, the MMO notes that the methodology has been followed as agreed previously and that pre-application surveys have been carried out and the resulting data used appropriately.	Detailed information on survey results is provided in Appendix 11.1. A summary of the key findings of the surveys is provided in Section 11.6.
MMO		The MMO notes that species/features of concern have been correctly identified. However it should be noted that for crab, lobster and whelk, trawling is not the usual and most effective method of sampling and as such reference to the data should be caveated to reflect this.	The effectiveness of sampling methods used in surveys has been noted in respect of shellfish species such as crab, lobster and whelk (Appendix 11.1 and section 11.6).
MMO	December 2017 PEIR Response	Potential Mitigation which could be included in the DCO: • Array and export cables to be buried to at least 1m depth where possible and appropriate mitigation such as cable armouring applied if not possible. • Cable protection methods to be used where adequate burial is not achievable e.g. at cable and pipeline crossings. • During construction, overnight working practices would be employed so that construction activities would be 24 hours where possible thus reducing the overall	A number of embedded mitigation measures have been incorporated as part of the project's design process. Those relevant to fish and shellfish ecology receptors are outlined in Section 11.7.1 and include, amongst other aspects: • Burial to at least 1m where possible. • Where cable burial is not achievable (i.e. due to the presence of hard ground and/or at cables crossing) cable protection will be used.

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		period for potential impacts to fish communities near Norfolk Vanguard • Commitment to soft start pile driving to enable mobile species to move away from the area of highest noise impact.	• During construction, overnight working practices could be employed; and • Implementation of soft start pile driving procedures.
National Federation of Fishermen's Organisations (NFFO)	December 2017 Consultation on PEIR	Ray form an important local stock to the fishing industry. Spurdog are also found in local concentrations and with their recovery are expected to form an important future fishery as it once was in the past. Monitoring studies on existing windfarms have been based upon AC technology and as the fisheries ecology chapter (CH 11) identifies, the magnitude of the magnetic field strength for a DC export cable is significantly higher than that for AC export cable (10x at 0 distance from the cable). The evidence provided does not provide any degree of certainty that the overall impact will be minor. This places greater emphasis on achieving and maintaining sufficient cable burial depth and in undertaking appropriate monitoring to establish whether or not significant adverse effects are taking place.	Consideration has been given within this assessment to the potential impacts of EMFs on fish and shellfish receptors (Section 11.7.5.4). In all cases, the assessment provided is based on the worst case scenario identified for the project (Table 11.11) and on best available information and research publications. As described in Section 11.7.1, cables will be buried where possible to at least 1m depth and protected where cable burial is not feasible. In the context of the assessment of EMFs, it is important to note that from the results of other post-consent monitoring conducted to date, there is no evidence to suggest that EMFs pose a significant threat to elasmobranchs at the site or population level, and little uncertainty remains (MMO, 2014) (see paragraph 277). In should be noted that the magnetic field values referred to in the NFFO response (provided in Table 11.24 and Table 11.25 for AC and DC cables respectively) are average values. These are based on modelling carried out for a range of different AC and DC cables of various voltages (Normandeau *et al*., 2011).
Departmental	December	Noise and electromagnetic fields are	Consideration has been given

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
Directorate of the Sea and Territories of Pas-de-Calais	2017 PEIR Response	generated by inter-array cables, the offshore substation and export cables (very high tension). The magnetic field (MF) is highest on the cable surface and decreases rapidly with distance to the cable. MF are lower when the cable is buried (installed under the seabed) or covered.	within the assessment to the potential impacts of EMFs associated with array, interconnector and export cables (Section 11.7.5.4). As described in Section 11.7.1, cables will be buried where possible to at least 1m depth and protected where cable burial is not feasible.
Departmental Directorate of the Sea and Territories of Pas-de-Calais	December 2017 PEIR Response	Long term risks are poorly known for most marine organism groups (cetaceans, elasmobranch, crustaceans, etc.). Yet many groups of animals are sensitive to minor variation of magnetic fields (cetaceans) or electrical fields (elasmobranch: rays and sharks). Impacts on noise disturbance and long-distance navigation are hardly known. Species using terrestrial magnetic fields to navigate and migrate (especially marine mammals) could be disturbed. Echolocation will help them avoid installations.	Consideration has been given within this assessment to the potential impacts of EMFs on sensitive fish and shellfish receptors associated with inter array, interconnector and export cables (Section 11.7.5.4). The assessment of potential impacts of EMFs on fish and shellfish receptors provided in this chapter is based on best available information and research publications and takes account of the results of monitoring work carried out to date in operational wind farms. Potential impacts of the project on cetaceans are discussed in Chapter 12 Marine Mammals.
Departmental Directorate of the Sea and Territories of Pas-de-Calais	December 2017 PEIR Response	Underwater structure that will be installed can have positive effect in terms of biodiversity (reef effect), the production and nursery of juveniles but can also have detrimental impacts such as the introduction of invasive species or the replacement of the pre-existing biodiversity by other species, modifying the baseline environment.	The potential impact of the introduction of hard substrate associated with project infrastructure on fish and shellfish receptors is assessed in Section 11.7.5.2. An assessment specific to benthic habitats is provided in Chapter 10 Benthic and Intertidal Ecology, including the potential for introduction of non-native species.
Departmental Directorate of the Sea and Territories of Pas-de-Calais	December 2017 PEIR Response	Important research programs could be associated to OWF projects, promoting technologies that minimise effects on EMFs sensitive species and engineering techniques that would be eco-friendly in the marine	Consideration has been given within this assessment to the potential impacts of EMFs on fish and shellfish receptors associated with array, interconnector and export

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		environment. These technologies are still in development and would benefit from further research.	cables (Section 11.7.5.4). In all cases, the assessment provided is based on the worst case scenario identified for the project (Table 11.11). The assessment of potential impacts of EMFs provided in this chapter is based on best available information and research publications and takes account of the results of monitoring work carried out to date in operational wind farms.
Natural England	December 2017 PEIR Response	It is stated that alternative methods, i.e. drilling or vibration may be required depending on the ground conditions. These alternative techniques need to be fully assessed throughout the ES, particularly under the fish and marine mammal's chapters.	Piles are generally expected to be driven but drilling may be required at some locations. In addition, other techniques, such as pile vibration, are also being considered. This will be confirmed post consent on receipt of more detailed geotechnical information. It should be noted that both pile vibration and drilling are considered to be low-noise foundation installation methods in comparison to pile driving. Therefore, for the purposes of this assessment under the worst case scenario (Table 11.11) it is assumed that all foundations will be installed using pile driving as this would result in the greatest noise impacts.
Natural England	December 2017 PEIR Response	Cumulative Impact Assessment: – If a phased approach is undertaken this needs to be an ever evolving process, particularly upon sensitive environmental receptors. The effect of one phase and any residual cumulative impacts will need to be strongly considered when any other potential phases are brought forward.	The project programme has been refined with the overall indicative duration of the construction period now being reduced to up to 4 years and either a single phase or two phase approach are proposed (Section 11.7.30). Three phase construction is no longer being considered as a design option.
Natural England	December 2017 PEIR Response	Associated construction impacts of 3-7 years: There is a danger that phasing the construction over a longer period of time could be potentially have far greater impacts than building it all at	Following concerns raised during consultation, the design envelope and the project programme have been refined

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		once. We encourage Vattenfall to refine their Rochdale Envelope and timescales in order to provide a more realistic assessment. The longer the phasing continues the longer the concurrent disturbance and therefore the greater the impact.	with the overall indicative duration of the construction window now being reduced to up to 4 years and either a single phase or two phase approach proposed (Section 11.7.30). Three phase construction is no longer being considered as a design option.
Natural England	December 2017 PEIR Response	It needs to be made clearer, much like in the appendix 11.1, that no specific surveys have been carried with respect to the Norfolk Vanguard EIA. How will potential project specific impacts be tested. Furthermore, the data is relatively old, particularly as the project advances, newer and more site specific data is needed.	No specific surveys have been carried out in relation to the Norfolk Vanguard EIA. Instead, data from surveys in areas which are relevant to the offshore project area (East Anglia THREE and the area of the former East Anglia FOUR which covers Norfolk Vanguard East) has been used. In addition, where relevant, data collected during surveys undertaken in the former East Anglia Zone have also been used. Given the location of East Anglia THREE and the former East Anglia FOUR, the findings of these surveys are highly relevant to the study area in respect of the project. Data from these site-specific surveys is considered appropriate to inform the fish and shellfish ecology baseline. This approach was agreed with the MMO and Cefas as part of the EPP (Evidence Plan Meeting, 21st March 2016; and 16th February 2017).
Natural England	December 2017 PEIR Response	Table 11.8: A key is required to inform the reader what the different colours represent as it is currently unclear.	A key has been added under Table 11.8.
Natural England	December 2017 PEIR Response	We agree that none of the protected areas designated include fish and shellfish species as qualifying features. However these habitats undoubtedly support (commercially) important fish species that would not necessarily	The importance of the protected areas in terms of key habitat to fish and shellfish species has been noted (Section 11.6.5). In addition, where

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		reside here if the habitat i.e. the qualifying features, were damaged. Therefore, the ecology of the fish are intrinsically linked to the protected site and this needs further consideration and discussion.	relevant, information provided in Chapter 10 Benthic and Intertidal Ecology in relation to impacts on protected areas has been used to inform the assessment.
Natural England	December 2017 PEIR Response	The primary driver for additional rock protection around the cables needs to be clarified. If the primary driver is for scour protection then this should be made clear, as we may prefer not to have additional rock in a soft sediment environment, if its only use is to reduce the potential effects of electromagnetic fields.	The key driver for the use of cable protection relates to avoiding risks associated with the presence of surface laid cables (i.e. snagging risks to commercial fishing and other vessels as well as risks to the asset itself). A number of mitigation measures have been incorporated as part of the project design process in order to minimise the potential impacts of Norfolk Vanguard on various receptors. Those that are relevant to fish and shellfish ecology are outlined in Section 11.7.1. In respect of embedded mitigation in relation to cable protection it should be noted that Norfolk Vanguard Limited has committed to using an HVDC solution in order to reduce the number of export cables and volume of cable protection. In addition, Norfolk Vanguard Limited is committed to burying offshore export cables where possible to a minimum depth of 1 m. This further reduces the need for cable protection. Additionally, this reduces potential effects associated with Electromagnetic Fields (EMFs) on sensitive fish and shellfish species.
Natural England	December 2017 PEIR Response	Section (11.7.1 (69)) talks about reducing the overall time construction activities are carried out to reduce the potential impacts upon fish	Following concerns raised during consultation, the design envelope has been updated

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		communities. The phased approach to construction contradicts this and represents an extended period of disturbance particularly if a break is incorporated, allowing little time for recovery to fish populations.	with the overall indicative duration of the construction phase window now being up to 4 years. In addition, either a single or two phase approach to construction is currently under consideration (Section 11.7.1). Three phase construction is no longer being considered as a design option.
Natural England	December 2017 PEIR Response	We advise that links between prey availability and bird species are made. The construction area overlaps with certain spawning areas which may represent a food source for a range of birds. If these aggregations move to other areas or are dispersed it may cause a loss in prey or require further foraging requirements. A similar situation may occur for populations that just move out of the area during disturbance.	The assessment provided in this chapter is focused on the impact of the project on fish and shellfish receptors. Potential impacts of the project on birds, including those associated with loss of prey are described in Chapter 13: Offshore Ornithology.
Natural England	December 2017 PEIR Response	Although a minor adverse significance is assessed for Sandeel, is there the potential to avoid "prime" habitat for this species when piling is occurring?	The assessment carried out in respect of construction noise on sandeels is based on the worst case scenario identified for the project (Table 11.11). It takes account of the relative importance of the area of the OWF sites and the wider area to sandeels as well as the outputs of the noise modelling for species with no swim bladder (based on Popper *et al.*, 2014 criteria). As shown in Figure 11.21, prime and subprime sandeel habitat is present across NV East and NV West. it is therefore likely that noise levels at which behavioural reactions on sandeels could be triggered would reach areas of prime or subprime sandeel habitat. In this context however, it should be noted that the presence of this habitat is based on sediment composition

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			rather than evidence of sandeel usage of the area. Therefore, the presence of suitable sediment does not necessarily imply that sandeels are significantly abundant in a particular area. The assessment of potential impacts on sandeels (including noise during construction) has taken account of the sediment characteristics of the offshore project area, but also of information on known spawning and nursery grounds, records from the IBTS surveys carried out in East Anglia THREE and the former East Anglia FOUR, as well as information on known fishing grounds and sandeel fishing records for the area.
Natural England	December 2017 PEIR Response	A good range of evidence is presented regarding SSC and we can agree with the conclusions that the levels presented shouldn't have an adverse effect. However, we reiterate that further site specific evidence needs to be collected to further confirm the evidence presented. Extrapolation of other projects data can only provide so much information.	The need of further surveys to characterise the area of the project was discussed with the Expert Topic Group (ETG) as part of the Evidence Plan Process (EPP) Evidence Plan Meeting, 16th February 2017. This concluded that data collected in East Anglia THREE, the former East Anglia FOUR (now Norfolk Vanguard East) and the former East Anglia Zone, were sufficient to provide an adequate current baseline in respect of fish and shellfish receptors.
Natural England	December 2017 PEIR Response	Recent research (https://www.sciencedirect.com/science/article/pii/S0006320717303634) has highlighted the effect of induced parturition caused by stress on elasmobranchs. Although the research focussed upon landed elasmobranchs the paper suggests that it could be stress induced as well. It would be interesting to consider the effects	Consideration has been given to the potential impact of Norfolk Vanguard on elasmobranch species throughout this chapter, Elasmobranch species identified as key receptors requiring assessment include various shark species which give birth

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
		from construction on those elasmobranchs that give birth to live young.	to live young (Table 11.10). There is no research or evidence currently available to inform an assessment of the potential impacts of offshore wind farm construction in terms of potential induced parturition caused by stress on elasmobranchs.
Natural England	December 2017 PEIR Response	There is no mention of elasmobranch species that lay eggs or their young. Egg cases cannot move out of the area and are fixed in position and therefore can be impacted at a greater level.	Specific reference has been made in the impact assessment to the limited mobility of egg cases and their potential increased sensitivity to impacts associated with Norfolk Vanguard (Section 11.7.4.1 and Section 11.7.4.2).
Natural England	December 2017 PEIR Response	Behavioural responses caused by TTS such as fish moving from preferred sites, needs to be studied in conjunction with the potential effects of prey availability for bird and other predatory fish species.	Potential impacts associated with changes in distribution of prey on predatory fish species have been assessed in Section 11.7.4.3. The potential impacts associated with this on ornithological receptors are assessed in Chapter 13 Offshore Ornithology.
Natural England	December 2017 PEIR Response	NV West and NV East are both located within high intensity spawning grounds for plaice. The report correctly identifies that in the grand scheme of things the project represents a small area. However, more site specific survey data may need to be presented to ensure no adverse impact is incurred upon spawning plaice.	Detailed information on the distribution of plaice spawning is provided in Appendix 11.1, including data provided in Ellis *et al.*, (2012) and data from the Channel Habitat Atlas for Marine Resource Management (CHARMS) Consortium. Whilst the project overlaps with an area defined as of high spawning intensity for plaice in Ellis *et al.,* (2012), it should be noted that this covers a very large area, extending over a large proportion of the Southern North Sea, the English Channel and the central section of the Central North Sea. Furthermore, highest eggs densities are generally recorded

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
			to the north, south and east of the OWF sites (Appendix 11.1).
Natural England	December 2017 PEIR Response	Sandeels are anticipated to be present in large numbers within the project area. PSA data has indicated areas of preferred sandeel habitat, with sections of prime habitat been identified within both project areas, primarily NV West. Due to their high site fidelity and little ability to recolonise they are at risk of being adversely affected. As a result, the potential to microsite/ avoid these prime areas could be a potential method of mitigation. Further data collection may also be needed.	Information on the potential distribution and abundance of sandeels in the area of the project is provided in Appendix 11.1 and referenced in the assessment where relevant. Note that the presence of sandeel prime/sub-prime habitat is based on sediment composition rather than evidence of sandeel usage of the area. Therefore the presence of suitable sediment does not necessarily imply that sandeels are significantly abundant in a particular area. The assessment of potential impacts on sandeels has taken account of the sediment characteristics of the offshore project area, but also of information on known spawning and nursery grounds, records from the IBTS surveys carried out in East Anglia THREE and the former East Anglia FOUR (now Norfolk Vanguard East), as well as information on known fishing grounds and sandeel fishing records for the area. On this basis and in the context of the extent of the Sandeel Assessment Area 1r (Figure 11.20), it is not considered that the offshore project area is of key importance to sandeels. The distribution of spawning and nursery grounds for these species, results of the IBTS surveys, known fishing grounds and sandeel fishing density records, all suggest that key sandeel areas are predominantly located north and east of the offshore project

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
			area.
Natural England	December 2017 PEIR Response	There needs to be a greater emphasis on the effect of introducing hard substratum in to protected sites and the effect upon species assemblages in these areas. Although the array does not overlap with any protected sites, the cable route goes through the SAC and any effects need to be determined in relation to this site.	The focus of this chapter is on fish and shellfish ecology. Specific issues relating to benthic ecology are discussed in Chapter 10 Benthic and Intertidal Ecology and the HRA report (doc 5.3). Where relevant, the findings of the benthic assessment are presented in support of this chapter. Consideration has been given in Section 11.7.5.2 to impacts associated with the introduction of hard substrate within NV East and West and the export cable (i.e. cable protection), including areas relevant to the SAC.
Natural England	December 2017 PEIR Response	Overall, NE agree with the conclusions presented regarding the potential impacts of EMFs upon a range of species. It is considered that any effects related to EMF would be temporary and most likely be short term behavioural changes. There has been evidence from certain OWF projects that have displayed increased numbers of elasmobranch species in post-construction surveys. However directly linking that to the presence of the cables and the operation of the windfarm has been difficult. Despite this, a minimum burial depth of between 1 m and 3 m should be retained. If the project gets consent any post-construction monitoring should identify an opportunity to study the effects of EMF further.	The assessment of the potential impact of electromagnetic fields (EMFs) on fish and shellfish species is based on the worst case scenario identified for the project (Section 11.7.5.4 and Table 11.11). In the context of the assessment of EMFs it is important to note that from the results of post-consent monitoring conducted to date, there is no evidence to suggest that EMFs pose a significant threat to elasmobranchs at the site or population level, and little uncertainty remains (MMO, 2014) (see paragraph 277). Consideration has been given in the cumulative assessment to the potential impact of EMFs associated with the project and other developments in the wider area on sensitive receptors (Section 11.8). As described in Section 11.7.1,

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
			cables will be buried where possible to a minimum of 1m depth and protected where cable burial is not feasible.
Natural England	December 2017 PEIR Response	It needs to be made clearer whether a cumulative impact assessment regarding impacts of construction noise has already been carried out. There doesn't seem to be much discussion around any associated impacts, considering there could be up to 7 projects within 100 km that could have an effect. NE believes there is a tendency in this section to still be focused on the immediate area of the Vanguard project and not the wider cumulative effects. The more projects that are piling sequentially and concurrently are obviously increasing the area of disturbance, but also reducing the areas the fish can move into to avoid this disturbance. This needs to be reflected in table 11.21, as the cumulative impact of noise from construction will not just affect species with spawning grounds in the Norfolk Vanguard area.	Consideration has been given to all fish and shellfish ecology receptors in relation to potential cumulative impacts with other projects as a result of construction noise (Section 11.8).
Natural England	December 2017 PEIR Response	Technical Report: The site-specific data or characterisation surreys that have been used to inform this report were collected in 2013. Although the data will provide a useful insight into the area, it is now becoming relatively old (over 4 years old), particularly in such an ephemeral environment as the North Sea. Therefore, we would recommend that if the project does receive consent further surveys are carried out to further inform and characterise the area, particularly for NV west. This will also help determine any potential effects caused by the windfarm post construction.	The need of further surveys to characterise the area of the project was discussed with Cefas and the MMO as part of the EPP (Evidence Plan Meeting, 16th February 2017). This concluded that data collected in East Anglia THREE, the former East Anglia FOUR and the former East Anglia Zone were sufficient to provide an adequate current baseline in respect of fish and shellfish receptors (Section 11.6).
Natural England	December 2017 PEIR Response	Technical Report: It is acknowledged that no further specific surveys have been carried out with respect to the Norfolk Vanguard EIA and this	Noted.

Consultee	Date /Document	Comment	Response / where addressed in the PEIR
		approach has been agreed in consultation with CEFAS and the MMO. However, we refer to and reiterate the point made above, regarding further site specific surveys needing to be carried out for the rest of the proposed array areas to further inform pre-construction data.	
Natural England	December 2017 PEIR Response	As above the report correctly identifies that the protected sites listed are designated based on the presence of habitats. However, these habitats support a range of important species that are not only commercially important but ecologically as well. If these sites become damaged or disturbed it could have a further effect on the species that reside here. This needs to be made clearer within this section.	The importance of the protected areas in terms of key habitat to fish and shellfish species has been noted (Section 11.6.5). In addition, where relevant, information provided in Chapter 10 Benthic and Intertidal Ecology and the HRA report (doc 5.3) in relation to impacts on protected areas has been used to inform the assessment.
Natural England	December 2017 PEIR Response	See comment 1 regarding further surveys being carried out. Ensuring any further surveys replicate the methodology outlined in table 3.1 would allow direct comparisons to be made and allow any changes to be quantitatively assessed.	The need of further surveys to characterise the area of the project was discussed with the Expert Group as part of the Evidence Plan Process (EPP). This concluded that data collected in East Anglia THREE and the former East Anglia FOUR were sufficient to provide an adequate current baseline in respect of fish and shellfish receptors.
Natural England	December 2017 PEIR Response	Overall there is a wide range of evidence regarding the location of spawning and nursery grounds and the biology and ecology of the fish species that the proposal will most likely affect. From the evidence presented it appears that the proposal will not have a significant effect on any one particular species.	Noted.

11.4 Assessment Methodology

11.4.1 Impact Assessment Methodology

10. The approach to the assessment of potential impacts on fish and shellfish ecology has been agreed in consultation with Cefas and the MMO through the EPP.

11. As specified in the Cefas and MCEU (2004) guidelines for offshore wind developments, the potential impacts of the project on fish and shellfish ecology have been assessed in relation to the following ecological aspects:

- Spawning grounds;
- Nursery grounds;
- Feeding grounds;
- Overwintering areas for crustaceans (e.g. lobster and crab);
- Migration routes;
- Conservation Importance;
- Importance in the food web; and
- Commercial importance.

12. The assessment of impacts has been undertaken separately for the construction, O&M and decommissioning phases.

13. Cumulative impacts relevant to fish and shellfish ecology arising from other marine developments have also been assessed. Similarly, consideration has been given to the potential for transboundary impacts to occur as a result of the project. The approach to the cumulative and transboundary impact assessment is described in section 11.4.2 and section 11.4.3 respectively.

11.4.1.1 Assessment sensitivities

14. The impact assessment presented within this chapter is subject to limitations which relate to knowledge gaps regarding the sensitivity of some species and/or species groups to particular impacts (e.g. impacts of noise on shellfish). Therefore, where necessary appropriate proxy species, or species groups have been used. Further uncertainties relate to the distribution of some species and the degree to which they access the offshore project area during key life history phases such as spawning or migration.

11.4.1.2 Sensitivity

15. Receptor sensitivity has been assigned on the basis of species specific adaptability, tolerance, and recoverability, when exposed to a potential impact. The following parameters have also been taken into account:

- Timing of the impact: whether impacts overlap with critical life-stages or seasons (i.e. spawning, migration); and
- Probability of the receptor-effect interaction occurring (e.g. vulnerability).

16. Throughout the assessment, receptor sensitivities have been informed by thorough review of the available peer-reviewed scientific literature, and assessments available on the Marine Life Information Network (MarLIN) database. It is acknowledged that the MarLIN assessments have limitations. These limitations have been taken in to account and other information and data accessed where relevant. Definitions of receptor sensitivity are provided in Table 11.3.

Table 11.3 Definition of Sensitivity levels for Fish and Shellfish Receptors

Sensitivity	Definition
High	Individual receptor (species or stock) has very limited or no capacity to avoid, adapt to, accommodate or recover from the anticipated impact.
Medium	Individual receptor (species or stock) has limited capacity to avoid, adapt to, accommodate or recover from the anticipated impact
Low	Individual receptor (species or stock) has some tolerance to accommodate, adapt or recover from the anticipated impact.
Negligible	Individual receptor (species or stock) is generally tolerant to and can accommodate or recover from the anticipated impact.

11.4.1.3 Ecological Value

17. Where appropriate, the ecological value of the receptor may be taken into account within the framework of the assessment. In these instances, 'value' refers to the importance of the receptor with respect to conservation status, role in the ecosystem, and geographic frame of reference. Note that for stocks of species which support significant fisheries, commercial value is also taken into consideration. Generic definitions of ecological values are provided in Table 11.4.

Table 11.4 Definitions of Value Levels for Fish and Shellfish Receptors

Value	Definition
High	Internationally or nationally important.
Medium	Regionally important or internationally rare
Low	Locally important / rare
Negligible	Not considered to be particularly important / rare

11.4.1.4 Magnitude

18. The magnitude of an effect is considered for each potential impact on a given receptor and is defined geographically, temporally and in terms of the likelihood of occurrence. The definitions of terms relating to the magnitude of a potential impact on fish and shellfish ecology are provided in Table 11.5.

19. With respect to duration of potential impacts, those associated with construction are considered to be short term, occurring over a maximum of between 2 to 4 years depending on the phasing option taken forward (single or two phase) and the time between commencement of phases.

20. Impacts associated with operation O&M are longer term, occurring over the design lifetime of the project (expected to be 30 years).

Table 11.5 Definitions of magnitude levels for fish and shellfish receptors

Magnitude	Definition
High	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key characteristics or features of the particular receptors character or distinctiveness.
Medium	Considerable, permanent / irreversible changes, over the majority of the receptor, and / or discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Low	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Negligible	Discernible, temporary (for part of the project duration) change, or barely discernible change for any length of time, over a small area of the receptor, and/or slight alteration to key characteristics or features of the particular receptors character or distinctiveness.

11.4.1.5 Impact significance

21. Table 11.6 applies the significance criteria to the assessment of an effect, taking into account the magnitude of effect and sensitivity of the receptor. In the context of impacts on fish and shellfish receptors, a low magnitude combined with a low sensitivity results in a minor significance. Those effects which are moderate or major are considered significant in Environmental Impact Assessment (EIA) terms.

22. The matrix is seen as a framework to aid understanding of how a judgement has been reached from the narrative of each impact assessment and it is not a prescriptive formulaic method. Therefore, defining impact significance is to some extent qualitative and reliant on professional experience, interpretation and judgement.

Table 11.6 Impact significance matrix

		Negative Magnitude				Beneficial Magnitude			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	*Major*	*Major*	*Moderate*	*Minor*	*Minor*	*Moderate*	*Major*	*Major*
	Medium	*Major*	*Moderate*	*Minor*	*Minor*	*Minor*	*Minor*	*Moderate*	*Major*
	Low	*Moderate*	*Minor*	*Minor*	*Negligible*	*Negligible*	*Minor*	*Minor*	*Moderate*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*

Table 11.7 Impact significance definitions

Impact Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or, could result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issues but are unlikely to be important in the decision-making process.
Negligible	No discernible change in receptor condition.

11.4.2 Cumulative Impact Assessment

23. With regards to cumulative impacts, already installed infrastructure, licenced activities and implemented measures have been assumed to constitute part of the existing environment to which receptors have adapted. There is also some limited information available on a number of planned offshore developments. The developments, activities and measures taken forward for cumulative assessment have been selected on the basis of the availability of information, probability and spatial overlap where relevant.

11.4.3 Transboundary Impact Assessment

24. The distribution of fish and shellfish species is independent of national geographical boundaries. The impact assessment has therefore been undertaken taking account of the distribution of fish stocks and populations irrespective of political limits. As a result, it is considered that a specific assessment of transboundary effects is

unnecessary. This approach is consistent with those taken for other projects in the region (e.g. East Anglia ONE OWF and East Anglia THREE OWF).

11.5 Scope

11.5.1 Study Area

25. The study area in respect of fish and shellfish ecology is shown in Figure 11.1. This has been defined with reference to the International Council for the Exploration of the Sea (ICES) statistical rectangles where the offshore project area is located. These are as follows:

- ICES rectangle 34F1 which encompasses the inshore section of the offshore cable corridor;
- ICES rectangle 34F2 which encompasses most of NV West, the western section of NV East and part of the offshore cable corridor; and
- ICES rectangle 34F3 which encompasses the eastern section of NV East.

26. A small area of the northern section of NV West is located outside the ICES rectangles mentioned above (in ICES rectangle 35F2). Due to the small proportion of this rectangle occupied by NV West, baseline information in respect of fish and shellfish ecology has not been analysed at ICES rectangle level for this rectangle.

27. Where appropriate, broader geographic study areas have been used for the purposes of describing the fish and shellfish existing environment and impact assessment. This has particular relevance to life history aspects such as the distribution of spawning grounds and migratory routes.

11.5.2 Data Sources

28. Key sources of data and information used to characterise the fish and shellfish ecology baseline and inform the assessment of potential impacts of the project are outlined below. Each of these data sources is described in further detail within Appendix 11.1:

- Results of adult and juvenile fish site specific surveys in the former East Anglia FOUR and East Anglia THREE in 2013;
- Results of site specific epibenthic characterisation surveys carried out in the former East Anglia FOUR and East Anglia THREE in 2013 and the former East Anglia Zone;
- MMO Landings weights data by species and ICES rectangle for the period 2007 to 2016;
- ICES International Herring Larvae Survey (IHLS) results (2007- 2016);

- International Bottom Trawl Survey (IBTS) results;
- Channel Habitat Atlas for Marine Resource Management (CHARM) (Carpentier *et al.,* 2009); and
- North Sea Ichthyoplankton survey data (van Damme *et al*., 2011).

29. In addition to the data sources described above, the following resources have been accessed to inform the assessment:

- Cefas publications;
- Institute for Marine Resources and Ecosystem Studies (IMARES) publications;
- Collaborative Offshore Wind Research into the Environment (COWRIE) reports;
- International Council for the Exploration of the Sea (ICES) publications; and
- Results of monitoring programmes undertaken in operational wind farms in the UK and other countries.

11.5.3 Assumptions and Limitations

30. Characterisation of the existing environment has been undertaken using the data sources listed above. These data sources, including their sensitivities and limitations, are described in further detail in Appendix 11.1.

11.6 Existing Environment

31. This section provides a summary of the fish and shellfish ecology baseline relevant to the project and identifies key fish and shellfish receptors requiring assessment. Further detailed information on the fish and shellfish ecology baseline is provided in Appendix 11.1

32. Receptors have been identified based on their commercial importance, location of spawning and nursery grounds, conservation importance and role within the North Sea food web.

11.6.1 Previous Surveys undertaken in the Former East Anglia Zone

33. Fish and shellfish characterisation surveys were undertaken in February and May 2013 in the area of the former East Anglia FOUR and in East Anglia THREE. These included otter trawl and 4m beam trawl sampling at various locations. Given the location of East Anglia THREE and the former East Anglia FOUR, the findings of these surveys are highly relevant to the study area in respect of the project. Data from these site-specific surveys, together with other publicly available data for the area (i.e. IBTS data) are therefore considered appropriate to inform the fish and shellfish ecology baseline. This approach was agreed with the MMO and Cefas as part of the EPP (Evidence Plan Meeting, 16th February 2017).

34. Further to the site-specific fish and shellfish surveys mentioned above, epibenthic surveys by means of 2m scientific beam trawl sampling were carried out in May 2013 at the East Anglia THREE (including the area of its export cable corridor) and in the area of the former East Anglia FOUR (Appendix 11.1). The aim of this type of survey is to characterise the epibenthic assemblage, including fish and shellfish species. As such, the results of the epibenthic surveys conducted at East Anglia THREE and the former East Anglia FOUR are also relevant and have been used to inform this chapter.

35. A summary of the site-specific surveys undertaken including sampling locations, frequency, duration and methodology is provided within Appendix 11.1.

36. The principal species recorded during these surveys are dab *Limanda limanda* and plaice *Pleuronectes platessa*. Other species frequently found in these surveys include whiting *Merlangius merlangus*, solenette *Buglossidium luteum*, sand goby *Pomatoschistus minutus*. lesser spotted dogfish/small spotted catshark *Scyliorhinus canicula*, lesser weever *Echiichthys vipera*, grey gurnard *Eutrigla gurnardus*, and common dragonet *Callionymus lyra*.

37. It should be noted that the surveys carried out primarily provide information on the distribution and abundance of demersal fish species, in light of the specific gear types used (otter trawl, 4m beam trawl and 2m scientific beam trawl). The presence and abundance of some species/species groups may therefore be misrepresented in the survey results (i.e. shellfish species, clupeids and diadromous migratory fish).

38. Detailed information of the site-specific surveys undertaken including results, sampling locations, frequency, duration and methodology is provided within Appendix 11.1.

11.6.2 International Bottom Trawl Surveys (IBTS)

39. IBTS data recorded in the study area (ICES rectangles 34F1, 34F2 and 34F3) have been analysed and used to further characterise the fish and shellfish community in the offshore project area.

40. Full survey results are provided in Appendix 11.1 including average relative abundance of the 50 most abundant species found in the IBTS expressed as Catch Per Unit Effort (CPUE) for the period 2007 to 2016. Further, for key fish receptors, figures showing their relative abundance and distribution in the study area and the wider North Sea, as derived from IBTS data (2007-2016), are also included in Appendix 11.1**.** A summary of the IBTS data is provided below.

41. The IBTS data suggests that species such as whiting, sandeels (*Hyperoplus lanceolatus, Ammmodytes tobianus and A. marinus*) dab, herring *Clupea harengus*, weevers and solenette are the most common species or species group (in the case of sandeels) found in the study area. Whiting and dab record greatest CPUE in rectangle 34F2 and rectangle 34F3, whilst sandeels, herring and weevers are found in higher numbers in rectangle 34F3 and solenette in rectangle 34F2 (Appendix 11.1).

11.6.3 Commercial Species

42. The principal commercial fish and shellfish species targeted in the study area have been identified based on UK MMO landings data by weight (tonnes) for those ICES rectangles which constitute the study area (34F1, 34F2 and 34F3) for the period 2007-2016.

43. Further detailed information including annual variability in UK landings by species and seasonality is provided in Appendix 11.1 together with information on landings from other countries, particularly the Netherlands and Belgium.

44. In rectangles 34F2 and 34F3, where NV West, NV East and the offshore section of the offshore cable corridor are located, plaice, sole, sprat *Sprattus sprattus*, and to a lesser extent cod, account for the majority of the landings by weight (Appendix 11.1). In rectangle 34F1, where the inshore section of the cable corridor is located, commercial landings by weight are dominated by shellfish species. Particularly, edible crab *Cancer pagurus*, whelks *Buccinum undatum*, lobster *Hommarus gammarus* and brown shrimp *Crangon crangon*. Herring accounts for the majority of fish landings by weight in this rectangle although the species represents less than 4% of the recorded total (Appendix 11.1).

11.6.4 Spawning and Nursery Grounds

45. The distribution of known spawning and nursery grounds in relation to the location of NV West, NV East and the offshore cable corridor is discussed in this section. This has been primarily informed by data provided in Coull *et al.* (1998) and Ellis *et al*. (2010; 2012). As outlined in Appendix 11.1, these papers are based on a review of published data and provide broad scale descriptions of the spatial and temporal extent of spawning grounds and spawning duration.

46. Species for which spawning or nursery grounds have been defined in areas that overlap with NV West, NV East and/or the offshore cable corridor are listed in Table 11.8 and illustrated in Figure 11.2 to Figure 11.11. This includes information on key spawning periods and spawning/nursery intensity, where known.

47. Note that both spawning and nursery grounds generally cover wide sea areas with the level of overlap between the offshore project area representing a small proportion of the overall grounds used by each species. (Figure 11.2 to Figure 11.11).

48. Spawning grounds for Dover sole, plaice, cod, whiting, lemon sole *Microstomus kitt*, mackerel *Scomber scombrus*, sprat and sandeel (Ammodytidae) have all been defined within the offshore areas occupied by the project.

49. Nursery grounds for all of the above species with the addition of herring, thornback ray *Raja clavata* and tope *Galeorhinus galeus* have been defined within the offshore project area. Note that in the case of thornback ray and tope, there is currently insufficient data on the occurrence of egg-cases or egg-bearing females in the spawning season with which to define spawning grounds. In the case of thornback ray, it is considered that these are likely to broadly overlap with nursery grounds (Ellis *et al*., 2012).

50. Most of the species listed in Table 11.8 are pelagic spawners, which release their eggs in the water column. Exceptions to this are herring and sandeel (Ammodytidae) which are substrate-specific demersal spawners. Thornback ray also lay eggs on benthic substrates although they are not known to have the same degree substrate-specific spawning requirements as herring and sandeels.

51. Further detailed information on the distribution of spawning and nursery grounds of the species described above, together with information relating to their ecology is provided in Appendix 11.1**.**

Table 11.8 Species with spawning and/or nursery grounds in NV West, NV East and the offshore cable corridor (Coull *et al.* (1998), Ellis *et al.* (2010;2012)

Species	Spawning season												Spawning Intensity			Nursery Intensity		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	OWF sites		Offshore Cable Corridor	OWF sites		Offshore Cable Corridor
													NV West	NV East		NV West	NV East	
Dover sole				●										n/a		n/a	n/a	
Plaice	●	●														n/a	n/a	
Cod		●	●											n/a				
Whiting																		
Lemon sole														n/a			n/a	
Herring													n/a	n/a	n/a			
Mackerel					●	●	●											
Sprat					●	●										n/a		n/a
Sandeel																		
Thornback ray				●	●	●	●	●					n/a			n/a	n/a	
Tope	Gravid females present year round												n/a					

(Spawning times and intensity colour key: orange= high intensity spawning/nursery grounds, green= low intensity spawning/nursery grounds, blue= spawning/nursery intensity not defined, grey= spawning period, ● = peak spawning, n/a= no overlap with spawning/nursery grounds)

11.6.5 Species of Conservation Importance

52. Fish and shellfish species of conservation importance which have the potential to be found in the study area are outlined in the following sections including:

- Diadromous migratory species;
- Elasmobranchs; and
- Other species with designated conservation status.

53. Detailed information on the ecology, conservation status and the use that these species may make of the offshore project area or areas in its proximity is provided within Appendix 11.1.

54. The export cable corridor overlaps with the Haisborough, Hammond and Winterton Special Area of Conservation (SAC). Qualifying features of this site include Sandbanks which are slightly covered by sea water at all times and *Sabellaria spinulosa* reefs (Appendix 11.1). Whilst no fish or shellfish species are amongst the qualifying features for designation of this site, the importance of the site in terms of provision of habitat to fish and shellfish species should however be recognised.

11.6.6 Diadromous Species

55. There is potential for a number of diadromous species to transit the offshore project area and/or its vicinity during the marine phase of their life cycle. These include:

- European eel *Anguilla anguilla;*
- Allis shad *Alosa alosa*;
- Twaite shad *Alosa fallax*;
- Sea lamprey *Petromyzon marinus;*
- River lamprey *Lampreta fluviatilis;*
- Atlantic salmon *Salmo salar*;
- Sea trout *Salmo trutta*; and
- Smelt *Osmerus esperlanus.*

56. The occurrence of species such as sea trout, European eel, smelt and lampreys is well documented off the Norfolk coast (Potter and Dare, 2003; Colclough and Coates, 2013). These and the remaining species listed above are also occasionally recorded in IBTS samples and MMO commercial landings statistics.

57. None of these species has been recorded during site specific fish and shellfish surveys carried out in NV East and East Anglia THREE (Appendix 11.1) and for the most, if present in the area, they would be expected in coastal areas (i.e. in inshore

areas in the proximity of the export cable corridor) rather than in NV West and NV East.

11.6.7 Elasmobranchs

58. Elasmobranchs (sharks and rays) have slow growth rates and low reproductive output compared to other species groups (Camhi *et al.,* 1998). Their resilience to fishing mortality is therefore low (Smith *et al.,* 1998) and recovery rates tend to be slow where fisheries have depleted abundance (Holden, 1974; Bonfil, 1994; Musick, 2005). As a result, a wide range of elasmobranchs have conservation status and /or declining stocks. Those potentially present in the study area are listed in Table 11.9.

59. Note that of these, only thornback ray, spotted ray *Raja montagui* and starry smoothhound *Mustelus asterias* were recorded during site specific surveys (Appendix 11.1).

Table 11.9 Elasmobranch species of conservation interest

	Common name	Scientific name
Sharks	Basking shark	*Cetorhinus maximus*
	Starry smoothhound	*Mustelus asterias*
	Smoothhound	*M. mustelus*
	Spurdog	*Squalus acanthias*
	Thresher shark	*Alopias vulpinus*
	Tope	*Galeorhinus galeus*
Skates and Rays	Blonde ray	*Raja brachyura*
	Cuckoo ray	*Leucoraja naevus*
	Common Skate Complex	*Dipturus intermedia/Dipturus flossada*
	Spotted ray	*Raja montagui*
	Thornback ray	*Raja clavata*
	Undulate ray	*Raja undulata*
	White skate	*Rostroraja alba*

11.6.8 Other Species of Conservation Interest

60. In addition to diadromous species and elasmobranchs there are a number of other species potentially present in the study area that are of conservation interest, being listed as UK BAP priority species. These are described in Appendix 11.1, along with other relevant conservation designations (e.g. OSPAR and IUCN listings). It should be noted that some of these species are commercially exploited in the area either

directly, (i.e. sole, plaice, cod) or indirectly, as by-catch and have been recorded during site specific surveys in the study area (Appendix 11.1).

11.6.9 Prey Species and Foodweb Linkages

61. Abundant species with high biomass such as sandeels (Ammodytidae) and clupeids (e.g. herring and sprat) play an important functional role in North Sea food web dynamics. Such species represent an important food web link because they occupy intermediate trophic levels, are significant predators of zooplankton and represent a key dietary component for a variety of aquatic and terrestrial predators. As described in Appendix.11.1 both landings data and the results of the IBTS indicate that these species groups are present in the study area. Species from both families were present in site specific surveys, albeit in relatively low abundances (Appendix 11.1).

62. Ammodytidae and clupeid species are important prey for piscivorous fish such as elasmobranchs, gadoids, sea bass *Dicentrarchus labrax*, mackerel, and sea trout, amongst others (ICES, 2005a; ICES, 2005b: ICES, 2006; ICES, 2008; ICES, 2009). The demersal egg mats of herring are also known to aggregate fish predators (Richardson *et al*., 2011). The diets of marine mammals such as seals *Phoca* spp. and harbour porpoise *Phocoena phocoena* are also subsidised by sandeels and clupeids to varying degrees (Santos and Pierce, 2003; Santos *et al.,* 2004). Both species groups are also an important resource for seabirds; this is especially true of sandeels which are important prey for kittiwakes, razorbills, puffins and terns, particularly during the breeding season (Wright and Bailey, 1996; Furness, 1990; Wanless *et al.,* 1998; Wanless *et al.,* 2005).

63. The ecology of these prey species is described in further detail within Appendix 11.1.

11.6.10 Key Fish and Shellfish Species

64. To reach agreement regarding which potential impacts and species would be taken forward for the project on fish and shellfish ecology, a method statement was produced and consultation undertaken with the MMO, Cefas, Natural England, the Environment Agency, the Eastern IFCA and the Wildlife Trust as part of the EPP (Evidence Plan meeting, 16th February 2017). The outputs of the EPP together with feedback provided by stakeholders within the scoping opinion and PEIR responses (Table 11.2) highlight herring, sandeels and elasmobranchs as key receptors to be considered within the assessment. This is with particular reference to piling noise (herring), increased suspended sediments (herring and sandeels) and electromagnetic field (EMF) generation (elasmobranchs). It was also recommended

that that commercially important species such as cod, sea bass, sole and plaice as well as species of conservation importance were assessed in the ES.

65. Key species identified, and the rationale for their inclusion within the assessment, are provided in Table 11.10. Detailed information regarding the ecology of these species and the use that they may make of the study area is provided in Appendix 11.1.

66. Note that for some impacts, species are not considered on an individual basis but by functional group (e.g. demersal or pelagic, fish or shellfish).

Table 11.10 Key fish and shellfish species taken forward for assessment of potential impacts

Relevant Fish and Shellfish Species	Rationale
Commercial demersal fish species	
Dover sole	• Abundant throughout the study area • UK BAP species • Commercially important in the study area • Low intensity spawning area overlaps with the offshore cable route and NV West • Low intensity nursery areas overlap with the inshore section of the offshore cable corridor
Plaice	• Abundant throughout the study area • UK BAP species • High intensity spawning area overlaps with NV West, NV East and the offshore section of the offshore cable corridor • Commercially important species in the study area • Low intensity nursery area overlaps with the inshore section of the export cable corridor
Cod	• UK BAP and OSPAR listed species and 'vulnerable' on the IUCN Red List • Commercially important species to local vessels in the study area • Low intensity spawning area overlaps with the export cable corridor and NV West • Low intensity nursery area overlaps with the offshore project area
Whiting	• Abundant throughout the study area • UK BAP listed species • Low intensity spawning and nursery areas overlap with the offshore project area
Sea bass	• Commercially important to local fisheries, and relatively abundant, particularly in areas in the proximity of the export cable corridor • Subject to new fisheries controls due to conservation concerns
Lemon sole	• Present throughout the study area • Spawning and nursery grounds overlap with the offshore cable corridor and NV West

Relevant Fish and Shellfish Species	Rationale
Commercial pelagic fish species	
Herring	• Present in the study area • UK BAP species • Low intensity nursery area overlaps with the offshore project area • Key prey species for fish, birds and marine mammals • Demersal spawner
Sprat	• Abundant in the study area • Important prey species for fish, birds and marine mammal species • Spawning area (undefined intensity) overlaps with the offshore project area • Nursery areas (undefined intensity) overlaps with NV East
Ammodytidae (Sandeels)	
Greater sandeel Lesser sandeel Smooth sandeel Small sandeel	• UK BAP species • Low intensity spawning and nursery areas in the study area • Key prey species for fish, birds and marine mammals. • Demersal spawner
Elasmobranchs	
Rays, Skates and Sharks	• Present in the vicinity of the study area • Some species are UK BAP or OSPAR listed and several are classified on the IUCN Red-List with landings restricted or prohibited • Some species have important local commercial value • The study area is situated within low intensity nursery area for tope and thornback ray (potential for these areas to also be used for spawning)
Diadromous fish species	
Sea trout	• Present in some East Anglian rivers • UK BAP listed species • Feeding grounds located in the vicinity of the offshore project area, particularly in areas relevant to the export cable corridor off the Norfolk coast • May transit/feed in the study area during marine migration
Atlantic salmon	• UK BAP listed species • No salmon rivers present in the proximity of the offshore project area • May occasionally transit/feed in the study area during marine migration
European eel	• Present in almost all East Anglian rivers • UK BAP species and listed as 'critically endangered' on the IUCN Red List • May transit/feed in the study area during marine migration
European smelt	• Considered to be of national importance • UK BAP listed species • Spawning populations present in some East Anglian rivers • May transit/feed in vicinity of the inshore section of offshore cable corridor
River lamprey Sea lamprey	• Present in some East Anglian Rivers • UK BAP listed species and sea lamprey listed by OSPAR as declining and/or threatened. • May transit/feed in vicinity of the study area during marine migration, more likely in areas relevant to the inshore offshore cable corridor (particularly in the case of river lamprey)
Twaite shad Allis shad	• UK BAP listed species • Potential to (rarely) transit/feed in vicinity of the study area during marine phase. If present at times this would most likely be in areas relevant to the inshore section of the offshore cable corridor

Relevant Fish and Shellfish Species	Rationale
Non-commercial fish species	
Characterising species of the fish assemblage (grey gurnard, lesser weever, solenette and Gobiidae spp)	• Present/ abundant throughout the study area • Possible prey items for fish, bird and marine mammal species
Shellfish species	
Brown (edible) crab	• Present in the study area, particularly in areas relevant to the offshore cable corridor • Commercially important species • May overwinter within the study area and the wider area
Lobster	• Present in the study area, particularly in areas relevant to the inshore section of the export cable corridor • Commercially important species
Brown and pink shrimp	• Present in the study area, particularly in areas relevant to the inshore section of the export cable corridor • Important prey species for fish • Commercially important
Whelk	• Becoming a commercially important species in the study area, particularly in areas relevant to the inshore section of the offshore cable corridor

11.6.11 Anticipated Trends in Baseline Condition

67. The existing baseline conditions within the study area described above are considered to be relatively stable in terms of fish and shellfish receptors. The fish and shellfish baseline environment of the Southern North Sea is primarily influenced by environmental factors and commercial fishing activity.

68. The baseline will continue to evolve as a result of global trends which include the effects of climate change as well as trends at the European level such as changes in fisheries regulations and policies.

11.7 Potential Impacts

69. An assessment of the potential impacts of Norfolk Vanguard on fish and shellfish receptors is given in the following sections. This has been informed by a literature review of the potential impacts of offshore wind developments on fish and shellfish species, evidence from research carried out at operational wind farms and information and feedback obtained through consultation with statutory and non-statutory stakeholders.

70. A summary of the potential impacts taken forward for assessment, including detailed information on the worst case scenarios assessed, is given in Table 11.11. Both

potential impacts and worst case scenarios have been defined in consultation with stakeholders as part of the EPP for the project.

11.7.1 Embedded Mitigation

71. A number of mitigation measures have been incorporated as part of the project design process in order to minimise the potential impacts of Norfolk Vanguard on various receptors. Those that are relevant to fish and shellfish ecology are outlined below:

- Careful site selection of the OWF sites and offshore cable corridor has been carried out to avoid, as far as possible, designated sites, including the Cromer Shoal Chalk Beds MCZ. It is not possible to avoid the Haisborough, Hammond and Winterton SAC (as detailed in Chapter 4 Site Selection and Assessment of Alternatives, Section 4.7.1).
- Norfolk Vanguard Ltd has reduced the maximum number of turbines from 257 to 200, while maintaining the maximum generating capacity of 1,800MW by committing to using 9MW to 20MW turbines.
- The overall indicative duration of the construction phase has been reduced to up to four years in up to two construction phases. This will result in a reduction of the overall period of disturbance to fish and shellfish receptors associated with construction activities.
- Norfolk Vanguard Ltd has committed to using HVDC technology in order to reduce the number of export cables and hence volume of cable protection. This results in the following mitigating features:
  - There will be two cable trenches instead of six for Norfolk Vanguard (and the same for Norfolk Boreas, considered in the CIA);
  - The volume of sediment arising from pre-sweeping and cable installation works is reduced;
  - The area of disturbance for pre-sweeping and cable installation is reduced;
  - The potential requirement for cable protection in the unlikely event that cables cannot be buried is reduced; and
  - The number of export cables required to cross existing cables and pipelines and the associated cable protection is reduced.
- Norfolk Vanguard Ltd is committed to burying offshore export cables where possible to a minimum depth of 1m. This reduces the need for cable protection. Additionally, this reduces potential effects associated with Electromagnetic Fields (EMFs). It should be noted that a detailed export cable installation study (CWind 2017 unpublished[1]) was commissioned by Norfolk Vanguard Limited

[1] CWind (2017). Norfolk Vanguard Offshore Windfarm Export Cable Installation Study

which confirmed that cable burial is expected to be possible throughout the offshore cable corridor, with the exception of cable and pipeline crossing locations. In order to provide a conservative and future-proof impact assessment, a contingency estimate has however been included in the assessment, should cable burial not be possible due to hard substrate (see Table 11.11).

- During construction, overnight working practices may be employed so that construction activities would be 24 hours where possible, thus reducing the overall period for potential impacts to fish communities near Norfolk Vanguard; and
- Soft start pile driving would be implemented to enable mobile species to move away from the area of highest noise impact during installation of foundations.

11.7.2 Monitoring

72. An In Principle Monitoring Plan (document reference 8.12) is submitted with the DCO application. In line with good practice, monitoring must have a clear purpose in order to provide answers to specific questions where significant environmental impacts have been identified. Monitoring should be targeted to address significant evidence gaps or uncertainty, which are relevant to the project and can be realistically filled. In this instance it is proposed that no further monitoring or independent surveys are required.

11.7.3 Worst Case

73. Worst case scenarios have been defined for each of the potential impacts of Norfolk Vanguard on fish and shellfish ecology and are outlined in Table 11.11. These have been identified based on the information on project design provided in Chapter 5 Project Description and taking account of the embedded mitigation outlined in section 11.7.1.

74. Based on the available data it is expected that the species distribution across NV East and NV West will be relatively homogenous. Furthermore, neither NV East or NV West significantly overlap spawning or nursery grounds of any species which may be of particular concern in the context of the ES.

75. The layout of the wind turbines will be defined post consent but will be based on the following maxima:

- Up to 1800MW in NV East, 0MW in NV West; or
- 0MW in NV East, up to 1800MW in NV West.

76. Any other potential layouts that are considered up to a maximum of 1800MW (e.g. 1,200MW in NV West and 600MW in NV East, 600MW in NV West and 1,200MW in NV East or 900MW in NV West and 900MW in NV East) lie within the envelope of these scenarios.

77. Given the relative homogeneity in the fish and shellfish baseline across NV West and NV East, in general terms it is considered that the 50% split of the maximum capacity between the two OWF sites constitutes the worst case scenario in terms of layout, as this would result in an overall greater area of impact on fish and shellfish receptors.

78. In addition to layout considerations, due regard has been given to the potential effects of different project construction phases on fish and shellfish receptors. Note that phasing is only applicable to the assessment of construction and decommissioning impacts and not to the assessment of impacts during the O&M phase.

79. Norfolk Vanguard Limited is currently considering constructing the project in one of the following phase options.

- A single phase of up to 1800MW; or
- Two phases, up to a combined 1800MW capacity.

80. Within Norfolk Vanguard, several different sizes of wind turbine are being considered in the range of 9MW and 20MW. In order to achieve the maximum 1,800MW export capacity there would between 90 (20MW wind turbines) and 200 (9MW wind turbines).

81. Up to two offshore electrical platforms, two accommodation platforms, two meteorological masts, two LiDAR, two wave buoys, plus offshore export cables, interconnector cables (linking offshore electrical platforms) and array cables (linking the wind turbines and the offshore electrical platforms) are also considered as part of the worst case scenario.

Table 11.11 Worst case assumptions

Impact	Parameter	Worst Case	Rationale
Construction			
Impact 1: Physical disturbance and temporary loss of seabed habitat	Disturbance footprints in the Offshore Wind Farm (OWF) sites due to cable laying operations, jack-up operations and seabed preparation works for turbine foundations	Worst case scenario for an individual foundation would be 20MW floating tension leg platforms with gravity anchors. Preparation area per 20MW platform = 8,100m² (based on approximately 90 x 90m). Total turbine seabed preparation area for 1800MW (all in NV East, all in NV West or split between both OWF sites): • 90 x 20MW turbines on GBS foundations (with a preparation area of approximately 90 x 90m) = 729,000m². • Two offshore electrical platforms seabed preparation = 15,000m² (approximately 75m x 100m per platform) • Two accommodation platforms seabed preparation = 15,000m² (approximately 75m x 100m per platform) • Two met masts seabed preparation = 2,513m² (based on 40m diameter) • Array cable trench – 600km length with average 20m pre-sweeping width = 12,000,000m² • Interconnector cable trench - 150km with 20m pre-sweeping width = 3,000,000m² (in the OWF sites and/or in the offshore cable corridor between NV East and NV West depending on the location of electrical platforms) • Jack up vessel footprints assuming 2 vessel movements per turbine = 316,800m² (based on 200 turbines x 2 movements x vessel footprint of 792m²) • Vessel anchor footprints (one vessel anchoring per turbine) = 30,000m² • Jack up vessel footprints assuming 2 vessel movements per offshore platform = 9,504m² • Boulder clearance – 53 boulders of up to 5m diameter = 1,041m² Worst case scenario total disturbance footprint = **16.1km²** Any other works associated with cable installation would be encompassed by the footprints outlined above.	This would result in the greatest footprint associated with disturbance/temporary loss of seabed habitat at the OWF sites. The temporary disturbance relates to seabed preparation and cable installation. The footprint of infrastructure is assessed in O&M Impact 1. It should be noted that the seabed preparation area for foundations is less than the footprint of the foundation scour protection.
	Disturbance footprints in the	• Boulder clearance = 432m² (up to 22 boulders of 5m diameter) • Pre-sweeping area which could be outside the ploughing area – 72,000m² (based on	This would result in the greatest footprint associated

Impact	Parameter	Worst Case	Rationale

	offshore cable corridor due to cable laying operations	minimum overlap of pre-sweeping area and ploughing footprint)
		• Maximum temporary disturbance for cable installation by ploughing = 6,000,000m^2 based on:
		    o Maximum total export cable trench length of 200km.
		    o Maximum width of temporary disturbance is approximately 30m, based on the disturbance impact for ploughing of a 10m wide trench with approximately 10m of spoil either side of the cable trenches.
		• Anchor placement – 600m^2 (based on four cable joints, two per cable pair with a footprint of 150m^2 each, assuming 6 anchors per vessel)
		• Total disturbance footprint = **6.1km^2**
		
		Disturbance footprints within the Haisborough Hammond and Winterton SAC. Note these areas are included in the calculations above:
		
		• Boulder clearance = 432m^2 (up to 22 boulders of 5m diameter)
		• Pre-sweeping area which could be outside the ploughing area – 50,000m^2
		• Maximum temporary disturbance for cable installation by ploughing = 2,400,000m^2 based on:
		    o Maximum total export cable trench length of 80km (40km per cable pair in the SAC).
		    o Maximum width of temporary disturbance is approximately 30m, based on the disturbance impact for ploughing of a 10m wide trench with approximately 10m of spoil either side for each export cable
		• Anchor placement – 300m^2 (based on two cable joints in the SAC)
		• Area of disposal site located within the offshore cable corridor 2,407,681m^2
		• Total disturbance footprint = **4.86km^2**
			with disturbance/temporary loss of seabed habitat associated with cable laying operations across the offshore cable corridor.

Impact 2: Increased Suspended Sediment Concentrations (SSCs) and	Suspended sediment concentrations and associated sediment deposition from cable and	The worst case suspended sediment and deposition is described in the assessments in Chapter 8 Marine Geology, Oceanography and Physical Processes based on the following volumes: **Drill arisings** • Wind turbine foundations based on worst case volume associated with 20MW monopile (45 turbines (50%) x 50m depth x 15m diameter) = 397,608m^3	This would result in the highest potential levels of SSCs and subsequent sediment re-deposition.

Impact	Parameter	Worst Case	Rationale
Sediment Re-deposition (for further detail on worst case parameters see Chapter 8, Marine Physical Processes)	foundation installation and seabed preparation in the OWF sites	• Meteorological masts - 2 x pin-pile quadropod = 1,131m^3 (based on 3m diameter piles x 4 piles x 2 metmasts x 20m depth) • Accommodation platforms - 2 x six legged pin-pile = 1,696m^3 (based on 3m diameter piles x 6 piles x 2 platforms x 20m depth) • Offshore electrical platforms - 2 x six legged pin-pile = 1,696m^3 (based on 3m diameter piles x 6 piles x 2 platforms x 20m depth) • Lidar - 2 x monopiles = 189m^3 Total = 402,320m^3 **Seabed preparation/ disposal** • 90 x 20MW turbines on floating tension leg platforms with gravity anchors (based on area described in Impact 1 and levelling depth of up to 5m) = 3,645,000m^3. • Two offshore electrical platforms based on area described in Impact 1 and 5m depth = 75,000m^3 • Two accommodation platforms based on area described in Impact 1 and 5m depth = 75,000m^3 • Two met masts based on area described in Impact 1 and 5m depth = 12,566m^3 • Array cable trench – 600km length with average 20m pre-sweeping width and 3m depth = 36,000,000m^3 • Interconnector cable trench 150km with average 20m pre-sweeping width and 3m depth = 9,000,000m^3 (in the OWF sites and/or in the offshore cable corridor between NV East and NV West depending on the location of the offshore electrical platforms) • Export cable pre-sweeping sediment disposal in the OWF sites = 1,800,000m^3 Total = 49,041,769.74m^3 It should be noted that seabed preparation is less likely to be required for piled foundations and, if required, would be significantly less than described above. Therefore the volume of drill arisings and seabed preparation outlined above are not cumulative.	
	Suspended sediment concentrations and associated sediment deposition from	The worst case suspended sediment and deposition is described in the assessments in Chapter 8 Marine Geology, Oceanography and Physical Processes based on the following volumes: The sediment disposed of as a result of the pre-sweeping activity for the offshore export	This would result in the highest potential levels of SSCs and subsequent sediment re-deposition.

Impact	Parameter	Worst Case	Rationale
	cable installation in the offshore cable corridor	cables in the offshore cable corridor would equate to about 600,000m^3 of sediment. Approximately 500,000m^3 would be within the Haisborough, Hammond and Winterton SAC (excluding the nearshore (10m water depth contour) where no pre-sweeping is proposed) and the remainder would be within the OWF sites (see impact 2A above). Following pre-sweeping, the sediment released due to trenching for the offshore export cables would equate to approximately 3,000,000m^3 of sediment, based on a maximum average depth of approximately 3m and a trench width of 10m at the seabed surface with a V shaped trench profile. This would be back filled naturally or manually. ***Disturbance volumes within the Haisborough Hammond and Winterton SAC. Note these areas are included in the calculations above*** The sediment released due to disposal of pre-swept sediment in the SAC would equate to approximately 500,000m^3. The sediment released at any one time would be subject to the capacity of the dredger. Disposal would be at least 50m from Sabellaria reef identified during pre-construction surveys. The sediment released due to trenching for the offshore export cables would equate to approximately 1,200,000m^3 within the SAC (based on 10m trench width with a V shaped profile x 3m maximum average depth x 2 trenches x 40km length in the SAC). This would be back filled naturally or manually.	
Impact 3: Underwater noise from piling	Underwater noise and vibration associated with piling for foundation installation	Spatial worst case (based on maximum hammer energy of 5,000kJ for installation of monopile foundations): • 90x 20MW turbines • 2x offshore electrical platforms • 2x met masts • 2x LiDAR • 2 x accommodation platforms • Up to two simultaneous piling events Temporal worst case (based on the installation of the maximum number of piles) (provides allowance for soft-start, ramp up and issues such as low blow rate, refusal).	The spatial worst case is a result of installation of monopile foundations using 5,000 hammer energies. This would result in largest spatial noise impact at any given time and hence maximum impact on fish and shellfish receptors. Consideration has also been given to the worst case scenario in terms of piling duration. This would be

Impact	Parameter	Worst Case	Rationale
		• 200x 9MW turbines on quadrapods (800 pin piles x 1.5 hour piling each) = 1,200 hours • 2x offshore electrical platforms with 6 pin piles (12 pin piles x 1.5 hours piling each) = 18 hours • 2x accommodation platforms with 6 pin piles (12 pin piles x 1.5 hours piling each) = 18 hours • 2x met masts on quadrapods (8 pin piles x 1.5 hours) = 12 hours • 2x LiDAR on monopiles (2 monopiles x 6 hours each) = 12 hours Total: 1,260 hours (52.5 days). This would account for 7.1% of the indicative construction window under the single phase approach and 3.6% of the indicative construction window under the two phase approach.	associated with the installation of the maximum number of piles.
Impact 4: Underwater noise from other construction activities	Underwater noise and vibration associated with seabed preparation, rock dumping, cable installation and construction vessels	Cable installation methods: Surface laid with cable protection where burial is not possible. • Ploughing; • Jetting; • Dredging; • Mass flow excavation; and • Trenching. Maximum length of cables: • Array cables: 600km • Interconnectors: 150km • Export cables: 400km Maximum number of vessels on site at any one time: 57 Maximum number of vessel transits during construction: 1,180	This would result in the greatest noise impacts as a result of project construction activities other than piling for foundation installation.
Impact 5: Underwater noise from UXO	Underwater noise associated with UXO clearance	Assumes UXO will be identified and it will not be possible to be avoided or removed from the seabed and disposed of onshore in a designated area.	This would result in a controlled detonation of the UXO being required and

Impact	Parameter	Worst Case	Rationale
			therefore in potential for associated noise impacts.
Operation and Maintenance (O&M)			
Impact 1: Permanent loss of seabed habitat	In the OWF sites through the presence of wind turbine and platform foundations, scour protection, array cables, inter-connector cables, and cable protection	Turbines Total worst case turbine footprint (1800MW) with scour protection, based on 90 x 20MW tension floating platform with a gravity anchor of 70 x 70m (350 x 350m with scour protection) = 11,025,000m^2. Array cable protection Up to 60km of cable protection may be required in the unlikely event that array cables cannot be buried (based on 10% of the length) resulting in a footprint of 300,000m^2 (based on protection width of 5m). Array cable protection at turbines 100m cable length x 5m width x 200 turbines = 100,000m^2 Array cable crossings protection 10 crossings x 100m x 10m = 10,000m^2 Interconnector cable protection Interconnector cable protection approaching platforms 100m cable length x 5m width x 2 platforms = 1,000m^2 Surface laid interconnector cable protection 5m width x 15,000m (10% of the length) = 75,000m^2 Interconnector cable crossings protection crossings – captured within export cable/array cable crossing total Platforms and other infrastructure Two offshore electrical platforms with scour protection 35,000m^2 Two accommodation platforms with scour protection 35,000m^2 Two met masts with scour protection 15,708m^2 Two wave buoys 300m^2 Two LiDAR monopiles with scour protection 157m^2	This would result in the maximum area of seabed habitat loss for fish and shellfish ecology receptors in respect of infrastructure within the OWF sites.

Impact	Parameter	Worst Case	Rationale
		Total WCS footprint = **11.6km²**	
	in the offshore cable corridor due to cable protection	Cable protection would be required at locations where the export cables cross other cables or pipelines; at the landfall HDD exit points; in the unlikely event that cable burial is not possible; and/or during the operation and maintenance phase should cables become unburied. Export cables • Crossings A total of eleven crossings (nine cables and two pipelines) are required for each cable pair (i.e. up to 22 crossings in total) resulting in a total footprint of 22,000m^2 (based on a width of 10m and length of 100m of cable protection per crossing). • Nearshore (within 10m depth contour) Cable protection may be required at each of the landfall HDD exit points. This would entail one mattress (6m length x 3m width x 0.3m height) plus rock dumping (5m length x 5m width x 0.5m height) at each exit point (up to two cable pairs) resulting in a footprint of 36m^2 • Unburied cables In the unlikely event that cable burial is not possible due to hard substrate being encountered, up to 10km per cable pair outside the SAC and 4km inside the SAC per cable pair (28km in total) could require additional protection resulting in a footprint of 140,000m^2 (based on protection width of 5m). Total WCS footprint = 0**.16km²** Of this total, 0.05km^2 could be within the Haisborough, Hammond and Winterton SAC at crossing locations and in the unlikely event that burial is not possible.	This would result in the maximum area of seabed habitat loss for fish and shellfish ecology receptors in respect of export cables.
Impact 2: Introduction of hard substrate	Introduction of hard substrate in the OWF sites through presence of	Based on the permanent infrastructure detailed for O&M Impact 1	This would result in the greatest introduction of hard substrate and therefore in the greatest extent of impacts on

Impact	Parameter	Worst Case	Rationale
	submerged infrastructure, scour and cable protection and in the export cable corridor due to cable protection		fish and shellfish receptors
Impact 3: Underwater noise during operation	Underwater noise and vibration associated with operational turbines and operation and maintenance activities	200 x 9MW operational wind turbines. Up to 440 vessel movements per year by various vessels associated with O&M activities (average of 1-2 vessel movements per day).	This results in the maximum potential for noise disturbance on fish and shellfish receptors during the operation and maintenance phase.
Impact 4: Electromagnetic Fields (EMFs)	In the OWF sites	Array cables: 600km of 66kV AC array cables. Interconnector cables: 150km	The maximum length of cables would result in the greatest potential for EMF related effects.
	In the offshore export cable	Maximum of 400km 320kV HVDC cables.	The maximum length of cables would result in the greatest potential for EMF related effects.
Decommissioning			
Impact 1: Disturbance and Temporary loss of habitat	Foundations (turbines and platforms)	Removal of foundations is likely to be limited to parts that are above the seabed. Impacts would be less than during the construction phase. Scour protection would likely be left *in situ*.	This would result in the maximum disturbance and temporary loss of habitat
	Array cables and protection	Some or all of the array cables and interconnector cables may be removed. Cable protection would likely be left *in situ*.	
	Export cables and	Some or all of the offshore export cables may be removed. Cable protection would likely be	

Impact	Parameter	Worst Case	Rationale
	protection	left *in situ*.	
Impact 2: Increased SSCs and sediment redeposition	See Chapter 8 Marine Physical Processes for further detail.		
Impact 3: Underwater Noise associated with foundations	Decommissioning of foundations	Cutting of up to 200 foundations - no piling required hence noise impact will be significantly smaller than during the construction phase.	This would result in the maximum potential noise impact associated with the decommissioning of foundations.
Impact 4: Underwater noise associated with other decommissioning activities	Decommissioning of cables and decommissioning vessels transit	Maximum number of vessels on site at a given time (assumed to be the same as for the construction phase (i.e. up to 57) In respect of cables, general UK practice will be followed, i.e. buried cables will simply be cut at the ends and left in-situ, with the exception of the inter-tidal zone across the beach where the cables would be at risk of being exposed over time. Excavation or jetting may be necessary to remove the cables in the inter-tidal zone.	This would result in the maximum potential disturbance associated with noise associated with decommissioning activities other than foundation decommissioning activities.

11.7.4 Potential Impacts during Construction

82. The potential impacts of the project on fish and shellfish receptors during construction are assessed below. As outlined in Table 11.11 these include the following:

- Physical disturbance and temporary loss of habitat;
- Increased SSCs and sediment re-deposition; and
- Underwater noise.

83. The worst case scenarios (discussed in section 11.7.3) are assessed with construction carried out in a single phase or in two phases. A detailed assessment of the single phase approach is presented and then highlights are given of any pertinent differences associated with the two phase approach.

84. Where relevant the magnitude of the impact is described separately for the OWF sites and the offshore export cable and the project as a whole. Note that the assessment of significance provided is always based on the magnitude of impact defined for the project as a whole.

11.7.4.1 Impact 1: Physical disturbance and temporary loss of seabed habitat

85. During the construction phase, activities such as foundation installation (for turbines, offshore electrical platforms, accommodation platforms and met masts) and installation of array, interconnector and export cables have the potential to result in physical disturbance and/or temporary loss of habitat to fish and shellfish receptors. Similarly, the presence of machinery on the seabed (i.e. jack up vessels legs, vessel anchors) could also result in physical disturbance or temporary habitat loss.

11.7.4.1.1 Single phase approach

86. As outlined in Table 11.11, the total area disturbed within the OWF sites would be 16.1km^2. This would account for a very small proportion of the area of the OWF sites (2.7%).

87. Similarly, the maximum area of disturbance associated with the installation of export cables would also be relatively small (6.1km^2).

88. The indicative construction programme (Chapter 5 Project Description) indicates that foundation installation during the single phase approach may last approximately 20 months whilst laying of the offshore export cables would take around 6 months. Laying of the array and interconnector cables would take around 19 months. Physical disturbance/temporary loss of habitat would be temporary and short term, and occur at localised discrete locations at any given time as construction progresses (i.e. in the immediate vicinity of infrastructure/machinery). Furthermore, the seabed

disturbed would be expected to return to its original condition over a relatively short time frame once construction had ceased in a given area and no significant impacts on the benthic community are anticipated in relation to disturbance during construction (impact assessed as minor adverse in Chapter 10 Benthic and Intertidal Ecology).

89. In light of the above, the magnitude of the effect of physical disturbance and temporary loss of habitat is considered to be low. This is considered the case in respect of the OWF sites, the offshore cable corridor and the project as a whole.

90. The majority of fish species found in the study area are highly mobile and would therefore be able to make use of suitable undisturbed areas in the vicinity of works. Most fish species under consideration have wide distribution ranges in the context of the small areas where physical disturbance and temporary habitat loss as a result of the project could occur. In general terms, fish species are therefore considered receptors of low sensitivity. This, in combination with the low magnitude of the impact assessed for the project, results in an impact of **minor adverse** significance.

91. It is recognised however, that species that depend on specific substrates (i.e. for burrowing or spawning) and species or life stages of reduced mobility, may be more susceptible to the impact of physical disturbance/temporary loss of habitat. In areas relevant to the project these include the following:

- Sandeels - require specific substrates on which to burrow as well as for spawning (demersal spawners);
- Herring - require specific substrates on which to lay their eggs (demersal spawners);
- Elasmobranch species with spawning grounds in the area of the project that lay egg cases on the seabed - thornback ray; and
- Shellfish species- have lower mobility in comparison to fish species and in some cases, carry their eggs or lay them on the seabed.

92. A separate assessment for these species/species groups is therefore given below.

Sandeels

93. Sandeels are dependent on the presence of adequate sandy substrate in which to burrow and are demersal spawners which lay their eggs on the seabed. Physical disturbance and temporary loss of seabed associated with the construction of the project could therefore result in detrimental impacts on this species.

94. As shown in Figure 11.21, Particle Size Analysis (PSA) data indicates the presence of preferred sandeel habitat (primarily sub-prime habitat) throughout the majority of the offshore project area, as well as the wider former East Anglia Zone. Sandeels

have been recorded within the study area by the IBTS, particularly in ICES rectangle 34F3 where the eastern section of NV East is located (see section 11.6.2) and during site specific surveys (Appendix 11.1). Therefore, sandeels are anticipated to be present in the offshore project area.

95. Analysis of IBTS data for the wider North Sea (Figure 11.16 to Figure 11.19), the distribution of high intensity spawning/nursery grounds for this species (Figure 11.10) and of sandeel fishing density in the wider North Sea (Figure 11.22), however, suggest that the offshore project area is of comparatively low importance to this species. Similarly, the findings of the sandeel habitat mapping exercise presented in Jensen *et al.* (2011) indicate that key areas to sandeels are located to the north and east of the project with the level of overlap between known sandeel grounds and the project being very small and limited to a discrete small section at the edge of the eastern boundary of NV East. When compared to the total sandeel grounds within Sandeel Assessment Area 1r, the overlap is minimal in its extent (see Figure 11.20).

96. Taking the above into account sandeels are considered to be receptors of medium sensitivity.

97. In light of the low magnitude of the impact associated with the project and the medium sensitivity of the receptor, the impact of physical disturbance and temporary habitat loss is assessed to be of **minor adverse** significance.

Herring

98. Herring are demersal spawners which require the presence of coarse substrate on which to deposit their eggs. There could therefore be the potential for a detrimental effect to occur on herring spawning as a result of physical disturbance and temporary habitat loss during the construction of the project.

99. It should be noted, however, that whilst this species is likely to be found in the study area at certain times (i.e. as suggested by landings data, section 11.6.3 and from IBTS data, Figure 11.12), there is no evidence to suggest that herring use areas within the offshore project area for spawning. As indicated by the results of the IHLS (Figure 11.13 to Figure 11.15) and the distribution of spawning grounds described in Coull *et al*. (1998) (Figure 11.7), the closest known spawning area of herring is located to the west of the offshore project area close to shore. The closest large-scale spawning ground is located towards the English Channel (Downs herring). Herring is therefore considered a receptor of low sensitivity.

100. Taking the low magnitude of the effect assessed for the project and the low sensitivity of the receptor the impact of physical disturbance and temporary loss of habitat is assessed to be of **minor adverse** significance**.**

Elasmobranchs - Thornback ray

101. Thornback rays lay eggs cases on the seabed and therefore have increased sensitivity to the effect of physical disturbance. However, spawning grounds for this species (as derived from the distribution of nursery grounds) (Figure 11.11) only overlap with the inshore section of the export cable corridor. Taking account of this and the overall extent of their spawning grounds, thornback ray is considered a receptor of low sensitivity.

102. Any direct disturbance to egg cases would be short term and localised (i.e. limited to export cable installation activities) and therefore the magnitude of the impact is considered low.

103. Taking the low magnitude of the effect assessed for the project and the low sensitivity of the receptor the impact of physical disturbance and temporary loss of habitat is assessed to be of **minor adverse** significance**.**

Shellfish

104. Shellfish species such as edible crab and lobster have adopted a reproductive strategy of high egg production to compensate for losses during egg extrusion and the extended incubation period (McQuaid *et al.,* 2009). Females are ovigerous, with the eggs remaining attached to the abdomen until hatching. In the case of edible crabs, females may remain buried in sediments when bearing eggs for periods ranging from four to nine months. Other species such as whelks lay demersal egg-cases which are often found attached to subtidal rocks, stones or shells (Ager, 2008).

105. Adult shellfish are also more limited in their mobility than fish species and may be less able to avoid areas where construction activity is occurring. In light of these considerations, both adults and egg masses (pre-hatching) could be vulnerable to physical damage. Therefore, receptor sensitivity is considered to be medium.

106. Taking the low magnitude of the impact assessed for the project and the medium sensitivity of the receptor, the impact of physical disturbance/temporary loss of habitat is assessed to be of **minor adverse** significance**.**

11.7.4.1.2 Two phase approach

107. The worst case total physical disturbance/temporary habitat loss associated with construction noted above for assessment of impacts of the single phase would remain the same under the two phase approach. Construction would however occur over two distinct phases. For installation of foundations, each phase is expected to last up to 8 months (rather than a single 20 month period), whilst for installation of array and interconnector cables, each phase is expected to last up to 7 months

(rather than a single 19 month period). For installation of export cables under the two phase approach, each phase would last for up to 3 months (instead of a single 6 month period).

108. Whilst these scenarios would mean that the effects occur over two separate periods, with a longer additive duration of disturbance, it is not considered that this would materially change the assessment of significance compared with a single phase approach. Note that physical disturbance, being highly localised, would happen once at each location as construction progresses and the sensitivity of the receptors would remain the same regardless of the overall duration and phasing of the construction programme.

11.7.4.2 Impact 2: Increased suspended sediment concentrations (SSCs) and sediment redeposition

109. An expert-based assessment of the potential increase in SSCs and associated sediment re-deposition resulting from the construction of the project is given in detail within Chapter 8 Marine Physical Processes. Relevant information included in the expert-based assessment is summarised here and has been used to inform the definition of the magnitude of the impact.

110. Activities associated with the construction phase that have potential to result in increased SSCs and sediment re-deposition include the following:

- OWF sites: seabed preparation for installation of foundations, drilling operations for foundation installation and array and interconnector cable installation; and
- Export cable installation.

11.7.4.2.1 Single phase approach

111. As described in Chapter 8 Marine Physical Processes and summarised in Table 11.11, the majority of the sediment released during construction at the OWF sites would be coarse material which would fall as a highly turbid dynamic plume upon its discharge, reaching the seabed within minutes or tens of minutes and within tens of metres along the axis of tidal flow from the location at which it was released. The resulting mound would be likely to be tens of centimetres to a few metres high. The small proportion of fine sand and mud would stay in suspension for longer and form a passive plume. This plume (tens of mg/l) would be likely to exist for around half a tidal cycle (i.e. approximately 6 hours). Sediment would settle to the seabed within approximately 1km along the axis of tidal flow from the location at which it was released. These deposits would be very thin (millimetres**).** In view of the small spatial and temporal extents of increased suspended sediments and deposition associated

with construction activities in the OWF sites, the magnitude of the impact is considered to be low.

112. With regards to the offshore cable installation, pre-sweep activities would result in the removal of up to 600,000m^3 of sediment. In addition, trenching activity could result in the release of up to 3,000,000m^3 of sediment. Whilst a relatively large quantity of material could be released, this would occur over a large area including up to two cable trenches and over a period of up to 6 months. It is therefore predicted that in water depths greater than 20m LAT (which are seen across the majority of the offshore cable corridor), peak suspended sediment concentrations would be typically less than 100mg/l, except in the immediate vicinity (a few tens of metres) of the release location. In shallow water nearer to shore (less than 5m LAT), the potential for dispersion is more limited and therefore the concentrations are likely to be greater, approaching 400mg/l at their peak. However, these plumes would be localised to within less than 1km of the location of installation and would persist for no longer than a few hours. Furthermore, following cessation of installation activities any plume would have been fully dispersed as a result of advection and diffusion. Chapter 8 Marine Physical Processes concludes that the magnitude of increase in suspended sediment concentrations would be low in the near field (likely to be of the order of several hundred metres but worst case of up to a kilometre from the offshore cable corridor) and negligible in the far field.

113. Sediment from cable laying activities would settle out onto the seabed. As discussed in Chapter 8 Marine Physical Processes, following completion of the cable installation activity theoretical bed level changes in excess of 0.2mm (and up to 0.8mm) are predicted at a distance of up to 20km from the cable trench and changes of up to 2mm within a few hundred metres of the inshore release locations. However, it is anticipated that under the prevailing hydrodynamic conditions, this material would be readily re-mobilised, especially in the shallow inshore area where waves would regularly stir the bed. Accordingly, outside the immediate vicinity of the offshore cable trench, bed level changes and any changes to seabed character are expected to be not measurable in practice.

114. Taking account of the anticipated levels of increase in SSCs and the expected level of sediment deposition, the magnitude of the impact with regards to the installation of the offshore export cable is, as for the OWF sites, considered to be low. Similarly, the magnitude of the impact taking account of the whole project (OWF sites and offshore export cable) is also considered to be low.

115. In general terms, adult and juvenile fish, being mobile, would be expected to rapidly redistribute to undisturbed areas within their habitat range, and are therefore considered receptors of low sensitivity. This, in combination with the low magnitude

of the effect associated with the project, would result in an impact of **minor adverse** significance.

116. It is recognised that species and life stages of relatively low mobility and those highly dependent on the presence of specific substrates may have increased sensitivity to the impact of SSCs and sediment deposition. For instance, eggs and early larval stages may drift passively in the water column or be present on benthic substrates. This results in reduced capacity to avoid areas impacted by increased SSCs and re-deposition of sediments and an increased susceptibility to the potential negative effects of the impact. Similarly, shellfish species, having lower mobility in comparison to most fish species, may be more susceptible as they may not be able to avoid areas affected by increased SSCs and re-deposition.

117. Therefore, separate assessments are given below for species highly dependent on the characteristics of the substrate, early life stages (eggs and larvae) and shellfish, as follows:

- Sandeels (demersal spawners);
- Herring (demersal spawners);
- Other species with known spawning grounds in the offshore project area; and
- Shellfish species.

Sandeels

118. Sandeels spend a significant proportion of their life cycle buried within the sea bed and are demersal spawners. Therefore, increased SSCs and sediment re-deposition associated with the project may have increased potential to adversely impact this species group.

119. Sandeels deposit eggs on the sea bed in the vicinity of their burrows. Grains of sand may become attached to the adhesive egg membranes. Tidal currents can cover sandeel eggs with sand to a depth of a few centimetres, however experiments have shown that the eggs are capable of developing normally and hatch as soon as currents uncover them again (Winslade, 1971). Buried eggs experiencing reduced current flow, and therefore lower oxygen tension, can have delayed hatching periods, which is considered a necessary adaptation to survival in a dynamic environment (Hassel *et al*., 2004).

120. In a feeding study of larval assemblages in the southern North Sea, Pérez-Domínguez and Vogel (2010) found that the presence of larval sandeel was correlated with high levels of suspended particulate matter, including silt. The absence of silt in their stomach contents indicated that sandeel larvae were able to successfully target prey items in turbid environments.

121. Research by Behrens *et al*. (2007) on the oxygenation in the burrows of sandeel *Ammodytes tobianus* found that the oxygen penetration depth at the sediment interface was only a few millimetres. Sandeels were, however typically buried in anoxic sediments at depths of 1-4cm. In order to respire, sandeels appear to induce an advective transport through the permeable interstice to form an inverted cone of porewater with 93% oxygen saturation.

122. In addition to direct effect on adults, eggs and larvae, increased SSCs and re-deposition associated with construction activity could also result in a change in the substrate characteristics causing a change/loss of habitat to sandeels. It should be noted, however, that for the most part any sediment re-deposited would be similar to that in the surrounding seabed and therefore no significant change in seabed sediment type is to be expected (Chapter 8 Marine Physical Processes).

123. From the above, it is apparent that sandeel eggs, larvae and adults are relatively tolerant to SSCs and sediment re-deposition and that there is little potential for significant changes in sandeel habitat to occur. As described previously for assessment of impacts in respect of temporary disturbance/loss of habitat (paragraph 95) sandeels are expected to be present in the offshore project area. However, evidence from IBTS surveys, the location of high intensity spawning and nursery grounds and the distribution of sandeel fishing activity and fishing grounds, suggest that the offshore project area is of comparatively low importance to this species in the context of Sandeel Assessment Area 1r. However, in view of their limited mobility and substrate dependence, they are considered receptors of medium sensitivity. Taking the low magnitude of effect assessed for the project and the medium sensitivity of the receptor the impact is assessed to be of **minor adverse** significance**.**

Herring

124. Herring are demersal spawners requiring the presence of a coarse substrate on which to lay their eggs. Therefore, increased SSCs and sediment re-deposition associated with the project may have increased potential to adversely impact this species.

125. Laboratory studies have established that herring eggs are tolerant to elevated SSCs as high as 300mg/l and can tolerate short term exposure at levels up to 500mg/l (Kiørboe *et al.,* 1988). These studies concluded that herring eggs suffered no adverse effects from suspended sediment concentrations in excess of the maximum levels expected from mining, dredging and similar operations. Herring eggs have been recorded to successfully hatch at SSCs up to 7,000mg/l (Messieh *et al.,* 1981).

126. Fine silt particles associated with increases in SSCs have the potential to adhere to the gills of larvae which could cause suffocation (De Groot, 1980). Griffin *et al.* (2009) suggested that larval survival rates could be reduced at SSCs as low as 250mg/l. Larvae of most fish species, including herring, are visual predators. Therefore, if visibility is reduced as a result of SSCs foraging success may be affected (Johnston and Wildish, 1981). There is evidence to suggest however that SSCs may enhance feeding rates by providing a visual contrast to prey items on the small perceptive scale used by the larvae. In addition, larvae may be subject to reduced predation from larger visual planktivores in turbid environments (Bone and Moore, 2008).

127. A study which exposed Pacific herring *Clupea harengus pallasi* larvae to suspensions of estuarine sediment and volcanic ash at concentrations ranging from 0 to 8,000mg/l (Boehlert and Morgan, 1985) found that maximum feeding incidence and intensity occurred at levels of suspension of up to 500mg/l above which feeding activity decreased.

128. In addition to impacts on eggs and larvae, increased SSCs and sediment re-deposition associated with the project could result in an impact on herring spawning grounds by means of changes in the characteristics of the substrate. It should be noted, however, that whilst this species is likely to be found in the study area at times (as suggested by landings data, section 11.6.3 and from records from the IBTS, Figure 11.12), there is no evidence to suggest that they use areas within the offshore project area as spawning grounds. As indicated by the results of the IHLS (Figure 11.13 to Figure 11.15) and the distribution of spawning grounds described in Coull *et al*. (1998) (Figure 11.7) the closest known spawning area of herring is located to the west of the offshore project area close to shore. The closest large scale spawning ground is located towards the English Channel (Downs herring) rather than in the OWF sites or the export cable corridor. It should also be noted that for the most part any sediment re-deposited would be similar to that in the surrounding seabed and therefore no significant change in seabed sediment type is to be expected (Chapter 8 Marine Physical Processes).

129. In light of the relative tolerance of herring eggs and larvae to increases in SSCs such as those associated with the construction of the project and the fact that the offshore project area and its vicinity is not expected to support herring during spawning, the receptor is considered to be of low sensitivity.

130. Taking the low magnitude of the effect assessed for the project and the low sensitivity of the receptor the impact of increased SSCs and sediment re-deposition is assessed to be of **minor adverse** significance.

Other species with spawning grounds in the offshore project area

131. As described in section 11.6.4, in addition to sandeels, there are a number of other fish species with defined spawning grounds located in areas relevant to the offshore project area. These include sole, plaice, cod, whiting, mackerel, sprat, lemon sole and thornback ray. Note that with the exception of thornback ray, these species are pelagic spawners and therefore do not have the same degree of spatial dependency on a specific substrate for spawning as sandeels or herring. Further, the spawning grounds of these species are extensive in the context of the localised areas where increased SSCs and re-deposition associated with the project may occur (see Figure 11.2 to Figure 11.6, Figure 11.8 and Figure 11.9,). In the particular case of thornback rays, whilst they lay egg cases on the seabed, their spawning grounds (inferred from the location of nursery areas) (Figure 11.11), only overlap with the inshore section of the export cable corridor.

132. Therefore, all these species are considered to be of low sensitivity. As discussed above, the magnitude of the effect for the project is low, giving an impact of **minor adverse** significance.

Shellfish species

133. According to the Marine Life Information Network (MarLIN) (Neal and Wilson, 2008), edible crab is considered to have a low sensitivity to increased SSCs (i.e. a change of 100mg/l for 1 month) and a high rating for recoverability. The sensitivity of edible crab to smothering is also considered to be low. This is based on a benchmark which considers a scenario where the population of a species or an area of a biotope is smothered by sediment to a depth of 5cm for one month. This assessment is based on crabs being able to escape from under silt and migrate away from an area, and consequently, smothering is not expected to result in mortality.

134. There is no MarLIN benchmark assessment for lobster. Lobsters do however belong to the same taxonomic family as the spiny lobster (Nephropidae) for which there is a benchmark assessment, thus providing a relevant comparison. The MarLIN conclude that spiny lobster is tolerant to increased SSCs and not sensitive to smothering. Given the physiological similarities between these species, it is reasonable to assume that sensitivities to increased SSCs and smothering will be similar for lobster. Similarly, in the case of shrimps, MarLIN benchmark assessment for brown shrimp (Neal, 2008), suggests this species to be not sensitive to increases in SSCs and of low sensitivity to smothering with very high recoverability.

135. In line with the above, in a review of the effects of elevated SSCs on biota, Wilber and Clark (2001) report that in studies examining the tolerance of adult crustaceans, the majority of mortality was induced by concentrations exceeding 10,000mg/l

(considerably higher than those generated by construction activity associated with the installation of foundations and cables).

136. There is limited information on the sensitivity of the common whelk to increased SSCs and deposition. MarLIN benchmark assessment for the dog whelk *Nucella lapillus* (which belongs to the same taxonomic order (Neogastropoda)), however, indicates that the species is not sensitive to increased SSCs and smothering, albeit the confidence/evidence in the assessment is low (Tyler-Walters, 2007).

137. Taking the relative tolerance of shellfish species to SSCs and smothering in the context of the small increases in SSCs and low level of re-deposition expected during the construction of the project, shellfish are considered receptors of low sensitivity. This, in combination with the low magnitude of the effect assessed for the project, would result in an impact of **minor adverse** significance.

11.7.4.2.2 Two phase approach

138. The principal difference between the two phase and single phase approach relates to the duration of time over which works may be undertaken. Under the two phase option installation of foundations during each phase is expected to last up to 8 (rather than a single 20 month period). Similarly, installation of the array and interconnector cables would occur over two phases, each being expected to last up to 7 months (rather than a single 19 month period) and installation of export cables over two 3 month phases rather than a single 6 month period. These scenarios would mean that increased SSCs and sediment re-deposition would occur in two separate periods, with a longer additive duration of disturbance. The localised nature of the impacts and the sensitivity of the receptors would however remain the same. For this reason, it is not considered that a two phase approach would materially change the assessment of significance to fish and shellfish receptors compared with a single phase approach.

11.7.4.3 Impact 3: Underwater noise from pile driving

139. Piles are generally expected to be driven but drilling may be required at some locations. In addition, other techniques, such as pile vibration, are also being considered (Chapter 5 Project Description). This will be confirmed post consent on receipt of more detailed geotechnical information.

140. It should be noted that both pile vibration and drilling are considered low-noise foundation installation methods in comparison to pile driving (Koschinski and Ludemann, 2013). Therefore, for the purposes of this assessment under the worst case scenario (Table 11.11) it is assumed that all foundations will be installed using pile driving as this would result in the greatest noise impacts.

141. The assessment is supported by the information provided in Appendix 5.3 (Underwater Noise Modelling, Appendix A), the outputs of which are summarised here.

11.7.4.3.1 Hearing in fish and shellfish

142. Very intense sounds may kill or injure marine animals. At lower levels, sound may impair their hearing, affect their ability to orientate, or make their vocalisations difficult to detect. Noise may induce changes in behaviour that may affect spawning migrations or disrupt foraging and feeding. It may cause chronic stress and associated physiological responses. In some cases, it may deny animals access to particular habitats, including preferred feeding grounds or spawning areas (Spiga *et al.,* 2012).

143. The potential impact of noise on fish and shellfish may vary depending on the hearing sensitivity of each particular species. From the limited studies conducted to date on the hearing of fish, it is evident that there are potentially substantial differences in auditory capabilities between individual fish species. The preferred approach to understand their hearing has therefore been to distinguish fish groups on the basis of differences in their anatomy and what is known about hearing in other species with comparable hearing systems (Hawkins and Popper, 2016). In line with this, the following groups have been proposed (Popper *et al.*, 2014):

- Fish species with no swim bladder or other gas chamber (e.g. dab and other flat fish species). These species are less susceptible to barotrauma and only detect particle motion, not sound pressure. However, some barotrauma may result from exposure to sound pressure;
- Fish species with swim bladder in which hearing does not involve the swim bladder or other gas volume (e.g. Atlantic salmon). These species are susceptible to barotrauma although hearing only involves particle motion, not sound pressure; and
- Fish species in which hearing involves a swim bladder or other gas volume (e.g. cod, herring and relatives, Otophysi). These species are susceptible to barotrauma and detect sound pressure as well as particle motion.

144. Hearing in shellfish species is poorly understood, however studies have shown that some species are able to detect sound. Lovell *et al.* (2005; 2006) reported that the prawn *Palaemon serratus* is capable of detecting low frequency sounds. Pye and Watson (2004) reported that immature lobsters of both sexes detected sounds in the range 20–1000 Hz, whilst sexually mature lobsters exhibited two distinct peaks in their acoustic sensitivity at 20–300 Hz and 1000–5000 Hz. It has also been suggested

that species that have complex statocysts, such as squid, cuttlefish and octopus may also be able to detect sounds (Budelmann, 1992).

11.7.4.3.2 Impact criteria

145. The noise impact criteria used for assessment of the impact of piling noise are shown in Table 11.12. These are based on Popper *et al.* (2014) which presents current best practice guidance on fish threshold criteria.

146. It is important to note that in some instances the noise levels used to define the Popper *et al.* (2014) criteria are the same for multiple effects. This is because data available to create the criteria is limited and therefore the approach is precautionary and most criteria are "greater than", (>) with a precise threshold not identified. All ranges associated with criteria defined as ">" are therefore somewhat conservative.

147. Furthermore, it should be noted that under Popper *et al.* (2014) guidance, the use of a quantitative approach for assessment of behavioural impacts on fish is not recommended, as the best research available is limited to very specific studies on species under artificial conditions. Behavioural criteria are instead described on the basis of the relative risk (high, moderate, low) to the animal at various distances from the source of noise (near (N), intermediate (I), and far (F)) (See Table 11.12). For the purpose of this assessment, in line with the definitions suggested in Popper *et al.* (2014), these distances have been considered as follows:

- Near: within tens of metres;
- Intermediate: within hundreds of metres; and
- Far: within thousands of metres.

Table 11.12 Impact criteria used in the assessment of piling noise on fish (Source: Popper *et al.*, 2014)

Category	Mortality/Mortal Injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behavioural
Fish with no swim bladder	>219 dB SEL_{cum} or >213 dB peak	>216 dB SEL_{cum} or >213 dB peak	>>186 dB SEL_{cum}	(N) High (I) Moderate (F) Low
Fish with swim bladder not involved in hearing	210 dB SEL_{cum} or >207 dB peak	203 dB SEL_{cum} or >207 dB peak	>186 dB SEL_{cum}	(N) High (I) Moderate (F) Low
Fish with swim bladder involved in hearing	207 dB SEL_{cum} or >207 dB peak	203 dB SEL_{cum} or >207 dB peak	186 dB SEL_{cum}	(N) High (I) High (F) Moderate

11.7.4.3.3 Noise modelling

148. Two piling source scenarios have been modelled to include monopile and pin pile foundations. These are:

- Monopiles using a maximum blow energy of 5,000kJ; and
- Pin pile installed using a maximum blow energy of 2,700 kJ.

149. For each foundation type, underwater noise modelling was undertaken at four representative locations, two in NV West and two in NV East. This showed the NV West locations to represent the worst case scenario given that the deeper water in NV West is conductive of higher noise source levels and greater overall noise propagation (Appendix 5.3: Underwater Noise Modelling, Appendix A).

Table 11.13 Underwater noise modelling locations

Location	NV West		NV East	
	South West	North East	South West	North East
Latitude	52.80098°N	53.04354°N	52.75323°N	52.91596°N
Longitude	002.44379°E	002.57117°E	002.76044°E	003.07780°E
Water depth	40m	35m	39m	28m

150. For calculating Cumulative Sound Exposure Levels (SEL_{cum}), the soft-start and ramp-up of hammer energy along with total duration and strike rate of the piling was considered. The ramp up takes place over the first 30 minutes of piling, starting at ten percent of maximum hammer energy, gradually increasing in hammer energy and strike rate until reaching the maximum hammer energy where it stays for the remaining time (Table 11.14 and Table 11.15). The monopile scenario contains 7,200 pile strikes over 255 minutes (4 hours and 15 minutes). The pin pile scenario includes four individual piles installed consecutively, which contains a total of 8,400 strikes over six hours (1 hour 30 minutes for each pin pile)

Table 11.14 Summary of the ramp up scenario used for calculating cumulative SELs for monopiles (Source: Appendix 5.3: Underwater Noise Assessment, Appendix A)

	Strike hammer energy (10%)	Ramp-up	Maximum hammer energy (100%)
Monopile hammer energy	500kJ	Gradual increase	5,000kJ
Number of strikes	150 strikes	300 strikes	6,750 strikes
Duration	10 minutes	20 minutes	225 minutes

Table 11.15 Summary of the ramp up scenario used for calculating cumulative SELs for a single pin pile (modelling assumes four consecutive piles installed at the same location) (Source: Appendix 5.3: Underwater Noise Assessment, Appendix A)

	Strike hammer energy (10%)	Ramp-up	Maximum hammer energy (100%)
Pin-pile hammer energy	270kJ	Gradual increase	2,700kJ
Number of strikes	150 strikes	300 strikes	1,650 strikes
Duration	10 minutes	20 minutes	60 minutes

151. For the SEL_{cum} criteria, a fleeing animal of 1.5m/s has been used (Hirata, 1999). All the impact thresholds from the Popper *et al.* (2014) guidance are unweighted. Further detailed information on the parameters used for modelling and the modelling methodology can be found in Appendix 5.3 (Underwater Noise Modelling, Appendix A).

152. The results of the modelling in terms of maximum, minimum and mean impact ranges for fish in respect of mortality and potential mortal injury, recoverable injury and Temporary Threshold Shift (TTS) are given in Table 11.16 to Table 11.22. Results are presented for installation of monopiles using the maximum blow energy (5,000kJ) and for installation of pin-piles using a maximum energy of 2,700kJ. As shown, installation of monopiles results in the greatest spatial impact ranges for fish. The outputs of the modelling carried out for monopiles have therefore been taken as the spatial worst case scenario for assessment (Table 11.11).

153. Fish species in which the swim bladder is involved in hearing are the most sensitive to the impact of piling noise. The outputs of the modelling indicate that the maximum impact ranges for installation of monopiles are up to few hundred metres for SPL_{peak} injury criteria and up to 8.8km for TTS (SEL_{cum}) (Table 11.16).

154. In addition to the worst case impact in terms of spatial extent, consideration has also been given within this assessment to the temporal worst case scenario. This is would be a result of the installation of the maximum number of piles (1,260 hours (52.5 days) of piling) (Table 11.11).

Table 11.16 Outputs of the noise modelling (monopiles, maximum hammer energy 5,000kJ) for the SW and NE locations modelled in NV West (Source: Appendix 5.3: Underwater Noise Assessment, Appendix A)

Fish Group	Metric	Potential Impact	Threshold	NV West SW Location			NV West NE Locations		
				Max	Mean	Min	Max	Mean	Min
Fish (no swim bladder)	SPL_{peak}	Mortality and potential mortal injury	>213 dB	83m	83m	82m	61m	61m	60m
		Recoverable injury	>213 dB	83m	83m	82m	61m	61m	60m
	SEL_{cum}	Mortality and potential mortal injury	>219 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	>216 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>>186 dB	8.8km	7.8km	7.0km	4.8km	4.6km	4.3km
Fish (swim bladder not involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	190m	190m	190m	140m	140m	140m
		Recoverable injury	>207 dB	190m	190m	190m	140m	140m	140m
	SEL_{cum}	Mortality and potential mortal injury	210 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>186 dB	8.8km	7.8km	7.0km	4.8km	4.6km	4.3km
Fish (swim bladder involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	190m	190m	190m	140m	140m	140m
		Recoverable injury	>207 dB	190m	190m	190m	140m	140m	140m
	SEL_{cum}	Mortality and potential mortal injury	207 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	186 dB	8.8km	7.8km	7.0km	4.8km	4.6km	4.3km

Table 11.17 Outputs of the noise modelling (pin-piles, maximum hammer energy 2,700kJ) for the SW and NE locations modelled in NV West Source: Appendix 5.3: Underwater Noise Assessment, Appendix A)

Fish Group	Metric	Potential Impact	Threshold	NV West SW Location			NV West NE Locations		
				Max	Mean	Min	Max	Mean	Min
Fish (no swim bladder)	SPL_{peak}	Mortality and potential mortal injury	>213 dB	60m	60m	59m	44m	44m	43m
		Recoverable injury	>213 dB	60m	60m	59m	44m	44m	43m
	SEL_{cum}	Mortality and potential mortal injury	>219 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	>216 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>>186 dB	4.6km	4.1km	3.7km	2.0km	1.9km	1.8km
Fish (swim bladder not involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	140m	140m	140m	100m	100m	100m
		Recoverable injury	>207 dB	140m	140m	140m	100m	100m	100m
	SEL_{cum}	Mortality and potential mortal injury	210 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>186 dB	4.6km	4.1km	3.7km	2.0km	1.9km	1.8km
Fish (swim bladder involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	140m	140m	140m	100m	100m	100m
		Recoverable injury	>207 dB	140m	140m	140m	100m	100m	100m
	SEL_{cum}	Mortality and potential mortal injury	207 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	186 dB	4.6km	4.1km	3.7km	2.0km	1.9km	1.8km

Table 11.18 Outputs of the noise modelling (monopiles, maximum hammer energy 5,000kJ) for the SW and NE locations modelled in NV East (Source: Appendix 5.3: Underwater Noise Assessment, Appendix A)

Fish Group	Metric	Potential Impact	Threshold	NV East SW Location			NV East NE Locations		
				Max	Mean	Min	Max	Mean	Min
Fish (no swim bladder)	SPL_{peak}	Mortality and potential mortal injury	>213 dB	78m	78m	77m	40m	40m	39m
		Recoverable injury	>213 dB	78m	78m	77m	40m	40m	39m
	SEL_{cum}	Mortality and potential mortal injury	>219 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	>216 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>>186 dB	7.5km	6.9km	6.4km	2.4km	2.0km	1.7km
Fish (swim bladder not involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	180m	180m	180m	92m	92m	91m
		Recoverable injury	>207 dB	180m	180m	180m	92m	92m	91m
	SEL_{cum}	Mortality and potential mortal injury	210 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>186 dB	7.5km	6.9km	6.4km	2.4km	2.0km	1.7km
Fish (swim bladder involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	180m	180m	180m	92m	92m	91m
		Recoverable injury	>207 dB	180m	180m	180m	92m	92m	91m
	SEL_{cum}	Mortality and potential mortal injury	207 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	186 dB	7.5km	6.9km	6.4km	2.4km	2.0km	1.7km

Table 11.19 Outputs of the noise modelling (pin-piles, maximum hammer energy 2,700kJ) for the SW and NE locations modelled in NV East (Source: Appendix 5.3: Underwater Noise Assessment, Appendix A)

Fish Group	Metric	Potential Impact	Threshold	NV East SW Location			NV East NE Locations		
				Max	Mean	Min	Max	Mean	Min
Fish (no swim bladder)	SPL_{peak}	Mortality and potential mortal injury	>213 dB	56m	56m	55m	28m	28m	27m
		Recoverable injury	>213 dB	56m	56m	55m	28m	28m	27m
	SEL_{cum}	Mortality and potential mortal injury	>219 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	>216 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>>186 dB	3.8km	3.5km	3.3km	320m	230m	150m
Fish (swim bladder not involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	130m	130m	130m	64m	64m	63m
		Recoverable injury	>207 dB	130m	130m	130m	64m	64m	63m
	SEL_{cum}	Mortality and potential mortal injury	210 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	>186 dB	3.8km	3.5km	3.3km	320m	230m	150m
Fish (swim bladder involved in hearing)	SPL_{peak}	Mortality and potential mortal injury	>207 dB	130m	130m	130m	64m	64m	63m
		Recoverable injury	>207 dB	130m	130m	130m	64m	64m	63m
	SEL_{cum}	Mortality and potential mortal injury	207 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		Recoverable injury	203 dB	< 10m	< 10m	< 10m	< 10m	< 10m	< 10m
		TTS	186 dB	3.8km	3.5km	3.3km	320m	230m	150m

11.7.4.3.4 Single phase approach

155. An assessment of the potential impact of underwater noise associated with piling activity is given below for fish and shellfish receptors.

156. In order to facilitate the assessment, and in line with Popper *et al.* (2014), fish receptors have been grouped into categories depending on their hearing system as outlined in Table 11.20.

157. In the particular case of shellfish, given the lack of specific impact criteria, the assessment has been based on a review of literature on the current understanding of the potential effects of underwater noise on shellfish species.

Table 11.20 Hearing Categories of the Fish Receptors (? denotes uncertainty or lack of current knowledge with regards to the potential role of the swim bladder in hearing)

Category	Fish Receptors relevant to Norfolk Vanguard
Fishes with no swim bladder or other gas chamber	Sole Plaice Sandeels Lemon sole Mackerel Solenette Elasmobranchs River and sea lamprey Lesser weever
Fishes with swim bladder in which hearing does not involve the swim bladder or other gas volume	Atlantic salmon Sea trout Smelt (?) Seabass (?) Grey gurnard (?) Gobies
Fishes in which hearing involves a swim bladder or other gas volume	Herring Sprat Cod Whiting European eel (?) Allis and Twaite shad

Mortality and Recoverable Injury

Fish with no swim bladder:

158. There is potential for mortality/potential mortal injury and recoverable injury to occur on fish with no swim bladder at ranges up to 83m SPL_{peak} and <10m SEL_{cum} (Table 11.16). Taking the small areas potentially affected and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be negligible.

159. The majority of fish receptors included within the group "fish with no swim bladder" (Table 11.20) are mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. They are therefore considered receptors of low sensitivity and the impact of mortality/recoverable injury is assessed to be of **negligible** significance.

160. An exception to this are sandeels, which given their burrowing behaviour and substrate dependence, may have limited capacity to flee the area compared to other fish species. They are therefore considered to be of medium sensitivity. This in combination with the negligible magnitude of the effect assessed, results in an impact of **minor adverse** significance.

Fish with swim bladder not involved in hearing:

161. There is potential for mortality/potential mortal injury and recoverable injury to occur on fish with swim bladders not involved in hearing at ranges up to 190m SPL_{peak} and <10m SEL_{cum} (Table 11.16). Taking the small areas potentially affected and the temporary, short term and intermittent nature of piling activity, the magnitude of the impact is considered to be negligible.

162. The majority of fish receptors included within the group "fish with swim bladders not involved in hearing" (Table 11.20) are mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. As such, they are considered receptors of low sensitivity. Taking this into account together with the negligible magnitude of effect assessed, mortality and recoverable injury associated with piling noise would result in an impact of **negligible** significance**.**

163. An exception to this are sand gobies as they have limited mobility and therefore potentially a reduced capacity to escape the areas affected by the greatest noise levels. Gobies are, however, abundant over wide areas of the North Sea and therefore any noise effects would impact only a small proportion of the population. Further, given the relatively short life cycle of this species (Teal *et al,.* 2009), they would be expected to recover quickly if subject to localised lethal or injury impacts associated with piling. As such, they are considered to be receptors of medium sensitivity. Taking the negligible magnitude of the effect, potential mortality and recoverable injury associated with piling noise would result in an impact of **minor adverse** significance.

Fish with a swim bladder involved in hearing:

164. There is potential for mortality/potential mortal injury and recoverable injury to occur on fish with swim bladders involved in hearing at ranges up to 190m SPL_{peak} and <10m SEL_{cum} (Table 11.16). Taking the small areas potentially affected and the

temporary, short term and intermittent nature of piling activity, the magnitude of the impact is considered to be negligible.

165. All the fish receptors included within the group "fish with swim bladders involved in hearing" (Table 11.20) are mobile and would be expected to vacate the area in which the impact could occur with the onset of ‘soft start’ piling. As such, they are considered receptors of low sensitivity. This, in combination with the low magnitude of effect identified, results in an impact of **negligible** significance**.**

Eggs and Larvae:

166. Impact criteria for potential mortality/potential mortal injury in eggs and larvae have been described in Popper *et al.* (2014) (>210 dB SEL_{cum} or >207 dB SPL_{peak}). The criteria are based on work by Bolle *et al.* (2012) who reported no damage to larval fish at SEL_{cum} as high as 210 dB re 1 µPa 2·s. Therefore, the levels adopted in Popper *et al.* (2014) are likely to be conservative. Given that the levels proposed in Popper *et al.* (2014) are similar to those described for fish species with a swim bladder not involved in hearing (210 dB SEL_{cum} or >207 dB SPL_{peak}) the modelled impact ranges for this category have been used to provide an indication of the potential impacts on fish eggs and larvae. As outlined in Table 11.16, these are as follows: 190m SPL_{peak} and <10m SEL_{cum}. Taking the small areas potentially affected and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be **negligible**.

167. Eggs and larvae would not be able to flee the vicinity of the foundations during piling, however prolonged exposure could be reduced by any drift of eggs/larvae due to water currents which may reduce the risk of mortality.

168. The distribution of eggs and larvae of a given species extends over wide areas at a given time. Whilst eggs and larvae would not be able to flee the vicinity of piling, the probability and frequency of interaction with piling events is expected to be low. In this context, the small amount of egg/larval mortality associated with piling in relation to the natural mortality rates during these life stages should be noted. Taking the above into account, larval stages are considered of medium sensitivity. This, in combination with the negligible magnitude of the effect, results in an impact of **minor adverse** significance.

Shellfish:

169. There are no specific criteria currently published in respect of shellfish species, however studies on lobsters have shown no effect on mortality, appendage loss or the ability of animals to regain normal posture after exposure to very high sound levels (>220 dB) (Payne *et al.,* 2007). Similarly, studies of marine bivalves (e.g.

mussels *Mytilus edulis* and periwinkles *Littorina spp*) exposed to a single airgun at a distance of 0.5m have shown no effects after exposure (Kosheleva, 1992).

170. The potential for piling noise to result in mortality/potential mortal injury or recoverable injury is therefore considered to be very low with the magnitude of the impact expected to be negligible. Given the relatively low mobility of shellfish species in comparison to most fish species, and therefore their reduced ability to avoid areas in the proximity of piling, they are considered to be receptors of medium sensitivity. This, in combination with the negligible magnitude of the effect results in an impact of **minor adverse** significance**.**

TTS and Behavioural Impacts

171. The outputs of the noise modelling for the spatial worst case scenario indicate that TTS may occur at distances of up to 8.8km for all the fish groups modelled (Table 11.16). Behavioural responses are anticipated to occur within this range and potentially in wider areas depending on the hearing ability of the species under consideration.

172. As shown in Table 11.11, in terms of the temporal worst case scenario, the maximum duration of piling would be equivalent of 52.5 days (1,260 hours).

173. Taking account of the spatial extent of the impact and the overall short duration of piling and its intermittent nature together with the fact that any effect associated with TTS and behavioural impacts would be temporary, the magnitude of the impact is considered to be low.

174. Impacts associated with TTS could result in reduced fitness, whilst behavioural impacts could cause changes in distribution, such as moving from preferred sites for feeding and spawning, or alteration of migration patterns.

175. Impacts on feeding activity are unlikely to cause long term, larger scale effects on fish populations given the wider availability of suitable feeding grounds in the region. There is concern however that behavioural responses such as avoidance, could have an adverse impact on spawning behaviour and migration of certain species.

176. The assessment of the impact of TTS and behavioural impacts has been focused on key species, selected on the basis of the presence of known spawning and nursery grounds in the area of the project, conservation status, commercial value and specific concerns raised during consultation. On this basis, the following species have been taken forward for detailed assessment:

- Sole;
- Plaice;

- Lemon sole;
- Mackerel;
- Sandeels;
- Seabass
- Cod;
- Whiting;
- Sprat;
- Herring;
- Elasmobranchs; and
- Diadromous species.

Sole, Plaice, Lemon sole and Mackerel:

177. A section of NV West overlaps with low intensity spawning grounds of sole and spawning grounds (intensity not defined) of lemon sole and mackerel (Figure 11.2, Figure 11.6 and Figure 11.8). In the case of plaice, NV West and NV East are both located within high intensity spawning grounds for the species (Figure 11.3). It should be noted, however, that the degree of overlap between the spawning grounds of these four species and the area impacted by TTS would be very small relative to the total area that the species use for spawning (see Figure 11.23, Figure 11.24, Figure 11.25 and 11.26). Furthermore, these four species are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

178. All four species lack a swim bladder and according to the criteria for behavioural impacts proposed in Popper *et al.* (2014) would be at high risk of behavioural impacts near the piling operation, at moderate risk at intermediate distances and at low risk when located far from the piling operation (Table 11.12). Taking the wide distribution ranges of these species, including areas used as spawning grounds, in the context of the potential zones where TTS and behavioural impacts could occur, they are considered to be receptors of low sensitivity. In combination with the low magnitude of the effect this results in an impact of **minor adverse** significance.

Sandeels:

179. Monitoring of lesser sandeels during seismic surveys has shown some behavioural reactions to source levels equivalent to 210 dB at 1 mPa with no increase in mortality or injurious effects. After the seismic shooting had ceased, normal behaviour resumed (Hassel *et al*., 2004). The results of this study indicate that effects of such noise levels on sandeel are likely to be short term, localised and constrained to behavioural level effects, with no longer term effects likely.

180. NV West and NV East overlap with low intensity spawning grounds for sandeels (Figure 11.10) and the eastern edge of NV East overlaps with known sandeels fishing grounds within Sandeel Assessment Unit 1r (Jensen *et al*., 2012; Figure 11.20). It should be noted, however, that the degree of overlap between sandeel spawning grounds and sandeel habitat impacted by TTS would be minimal relative to the total suitable habitat over which these species are distributed and spawn (see Figure 11.27).

181. Sandeels lack a swim bladder and according to the criteria for behavioural impacts proposed in Popper *et al*. (2014) would be at high risk of behavioural impacts close to piling operations, at moderate risk at intermediate distances and at low risk when located far from the piling operation (Table 11.12).

182. Taking the above into account together with their seabed habitat specificity, sandeels are considered to be receptors of medium sensitivity. This, in combination with the low magnitude of effect results in an impact of **minor adverse** significance.

Sea bass:

183. Sea bass is a species commercially important to local fisheries, and relatively abundant in the offshore project area, particularly in areas in the proximity of the export cable corridor. The species are currently subject to new fisheries controls due to conservation concerns (Appendix 11.1).

184. A range of studies have been carried out on the potential behavioural impact of underwater noise on this species with increases in motility and changes in swimming performance reported in response to impulsive sounds (Neo *et al*., 2015). Changes in responsiveness to visual stimulus have also been reported in sea bass exposed to playback piling noise (Everley *et al.,* 2015) and startle responses as a result of exposure to low frequency sounds (Kastelien *et al.,* 2008).

185. As noted in Table 11.16, TTS could occur at ranges up to 8.8km from piling. Sea bass falls within the category of fish with a swim bladder which is not involved in hearing. Following Popper *et al.,* (2014) criteria for behavioural impacts for this category (Table 11.12), sea bass would be at high risk of behavioural impacts near the piling operation, at moderate risk at intermediate distances and at low risk when far from the piling activity.

186. As mentioned above, sea bass are anticipated to be more abundant in the proximity of the offshore cable route (where they are targeted by fisheries), rather than in the OWF sites. On this basis, the potential for interaction with piling noise would be limited. Taking this into account together with the relatively small areas where TTS and behavioural impacts may occur in the context of the wide distribution range of

this species, a low sensitivity is assigned. In combination with the low magnitude of the effect the impact is of **minor adverse** significance**.**

Cod, Whiting and Sprat:

187. NV West and NV East overlap with low intensity spawning grounds of cod and whiting and with spawning grounds (intensity not defined) of sprat (Figure 11.4, Figure 11.5 and Figure 11.9). It should be noted, however, that the degree of overlap between the spawning grounds of these three species and the area impacted by TTS would be very small relative to the total area that the species use for spawning (see Figure 11.28, Figure 11.29 and Figure 11.30). Furthermore, these species are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

188. These three species have a swim bladder which is involved in hearing and according to the criteria for behavioural impacts proposed in Popper *et al*. (2014) would be at high risk of behavioural impacts near and at intermediate distances and at low risk when located far from the piling operation (Table 11.12). Taking the potential zones where TTS and behavioural impacts could occur, in the context of the wide distribution ranges of these species (including spawning areas), they are considered receptors of low sensitivity. This, in combination with the low magnitude of the effect, results in an impact of **minor adverse** significance.

Herring:

189. Blaxter and Hoss (1981) found startle responses in herring at received levels between 122–138dB re 1µPa and observed that the response depended on the size of the herring. Skaret *et al.* (2005) found that herring spawning close to the seabed did not show any sign of a reaction towards a survey vessel passing at a standard survey speed (10–11 knots) at a distance of 8–40m at sound pressure levels ranging from 70-150 dB re 1 µPa 1 Hz. A seismic study on adult herring involving sound exposure levels (SEL) ranging from 125 to 155 dB re 1 µPa2 (Peña *et al.,* 2013) found that no changes were observed in swimming speed, swimming direction, or school size. The lack of a response to the seismic survey was interpreted as a combination of a strong motivation to spawn, and a progressively increased level of tolerance over time.

190. Herring generally adopt low-risk behavioural strategies (Fernö *et al*., 1998; Axelsen *et al*., 2000), but at times predator avoidance must be balanced with other activities that affect vigilance. During the feeding season, the reaction towards vessels is low compared with the wintering period (Misund, 1994) and the act of reproduction during the spawning season takes precedence over avoidance reactions that are evident at other times of the year (Nøttestad *et al.,* 1996'; Skaret *et al*., 2003). Mohr

(1971) observed that ripe herring swimming close to the sea bed showed no avoidance reactions to a moving trawl, consistent with high reaction thresholds during spawning.

191. There are no known herring spawning grounds in the area of NV West and NV East (Figure 11.7) and the results of the IHLS do not suggest the OWF sites sustain herring spawning (Figure 11.13, Figure 11.14 and Figure 11.15). Furthermore, impact ranges associated with TTS are not expected to overlap with known spawning grounds/or areas of high herring larval density (Figure 11.31).

192. Herring have a swim bladder which is involved in hearing and according to the criteria for behavioural impacts proposed in Popper *et al*. (2014) would be at high risk of behavioural impacts near and at intermediate distances from the piling operation and at moderate risk when located far from the piling operation (Table 11.12).

193. Given the location of herring spawning grounds in respect of the OWF sites, and the ranges for potential TTS and behavioural impacts expected from the project, the potential for spawning herring to be affected would be minimal. However, the substrate specific spawning behaviour is taken into account and therefore herring is considered a receptor of medium sensitivity. This in combination with the low magnitude of effect, results in an impact of **minor adverse** significance.

Elasmobranchs:

194. Elasmobranchs are thought to be sensitive to the particle displacement component of sounds within the range of 20–1000 Hz (Casper and Maan, 2006; 2010), although laboratory studies have raised questions over sharks' capability of detecting sounds in the acoustic far field (Casper and Mann, 2006).

195. Under the spatial worst case piling scenario (5,000kJ hammer energy) TTS may occur at ranges of up to 8.8km (Table 11.16). Elasmobranchs lack a swim bladder and according to the criteria for behavioural impacts proposed in Popper *et al*. (2014) would be at high risk of behavioural impacts near the piling operation, at moderate risk at intermediate distances and at low risk when located far from the piling operation (Table 11.12).

196. The potential areas affected by TTS and behavioural impacts are very small in the context of the wide distribution ranges of elasmobranch species, including those relating to spawning/nursery grounds for relevant species (namely thornback ray and tope) (Figure 11.32 and Figure 11.33) and therefore any impacts associated with piling would be expected to be minimal.

197. Considering the above, elasmobranchs are considered receptors of low sensitivity. This in combination with the low magnitude of the effect results in an impact of **minor adverse** significance.

Diadromous species:

198. Diadromous species included in the assessment comprise, river lamprey, sea lamprey, salmon, sea trout, allis shad and twaite shad, European eel and smelt.

199. Under the spatial worst case piling scenario (5,000kJ hammer energy) TTS may occur at ranges of up to 8.8km (Table 11.16).

200. Potential ranges of behavioural impacts would depend on the hearing sensitivity of each species. As shown in Table 11.20, river and sea lamprey fall within the species which lack a swim bladder category; salmon, sea trout and smelt, under the species with a swim bladder that is not involved in hearing and European eel and allis and twaite shad under the species with a swim bladder that is involved in hearing. According to Popper *et al.* (2014) the risk of behavioural impacts on these species would be:

- For species with no swim bladder and species with swim bladder which is not involved in hearing: high near the piling operation, moderate at intermediate distances and low when located far from the piling operation; and
- For species with swim bladders involved in hearing: high near the piling operation and at intermediate distances and moderate when located far from the piling operation.

201. It should be noted, however, that diadromous species are only likely to occur occasionally in the area of the OWF sites and therefore the potential for these species to be subject to piling noise is very low. Furthermore, given the distance from NV West and NV East to the coast and therefore to rivers, there is no potential for piling noise to affect these species during critical periods of their migration such as river entry and river exit. In light of the above, diadromous species are considered receptors of low sensitivity. This in combination with the low magnitude of the impact results in an impact of **minor adverse** significance.

Indirect impacts on fish species as a result of behavioural disturbance to prey species

202. Fish species such as sandeels and clupeids (herring and sprat) play an important role in the North Sea's food web as prey for birds, marine mammals and piscivorous fish. There may therefore be potential for changes in the behaviour of these prey species associated with piling noise to result in indirect impacts on the species that feed on them.

203. An assessment of the potential impact of changes in prey availability as a result of piling noise in respect of piscivorous fish is given below. Potential impacts on other receptors groups (namely marine mammals and birds) are assessed in Chapter 12 Marine Mammal Ecology and Chapter 13 Offshore Ornithology and are therefore not discussed here.

204. The outputs of the noise modelling for the spatial worst case scenario indicate that TTS may occur at distances of up to 8.8km for all the fish groups modelled. Behavioural responses are anticipated to occur within this range and potentially in wider areas depending on the hearing ability of the species under consideration.

205. As shown in Table 11.11, under the temporal worst case scenario (maximum number of piles) the overall duration of piling would be equivalent to 52.5 days (1,260 hours).

206. Taking account of the spatial extent of the impact and the overall short duration of piling and its intermittent nature together with the fact that any effect associated with TTS and behavioural impacts would be temporary, the magnitude of the impact is considered to be low.

207. Whilst it is recognised that changes in the distribution of key prey species to piscivorous fish may occur as a result of piling noise, as described in the assessment provided above in respect of TTS and behavioural impacts on herring, sandeels and sprat, significant impacts (i.e. above minor significance) have not been identified on any of these species. In addition, where avoidance or behavioural reactions take place, these would occur on both prey species and the fish species that feed on them. Taking this into account together with the wide distribution ranges of both, prey and piscivorous fish, the sensitivity is considered to be low. This, in combination with the low magnitude of the effect results in an impact of **minor adverse** significance.

11.7.4.3.5 Two phase approach

208. The principal difference between the two phase and single phase approach relates to the overall period of time over which works may be undertaken. Under the two phase option the indicative construction window would be up to 4 years. This scenario would mean that piling and the associated underwater noise would be produced in two consecutive separate periods. However, the areas affected by noise and the overall duration of piling would remain the same as well as the total area where a potential change in distribution of prey may occur. Therefore, both the sensitivity of the receptors and the magnitude of the impact would also be expected to remain the same. For this reason, it is not considered that a two phase approach

would materially change the assessment of significance to fish and shellfish receptors compared with a single phase approach.

11.7.4.4 Impact 4: Underwater noise from other construction activities

11.7.4.4.1 Single phase approach

209. This section assesses the potential impacts associated with underwater noise during construction activities other than pile driving (Section 11.7.4.3).

210. Potential sources of underwater noise include seabed preparation, rock dumping and cable installation. Of these, the activity that has the greatest potential noise impacts is cable installation and has therefore been assessed as a worst-case scenario (Table 11.11).

211. The cable installation methods that are currently being considered are:

- Surface laid with cable protection where burial is not possible;
- Ploughing;
- Jetting;
- Dredging;
- Mass flow excavation;
- Trenching; and
- Rock dumping for protection of the cables.

212. There are no clear indications that underwater noise caused by the installation of sub-sea cables poses a high risk of harming marine fauna. However, it is considered that there is a potential for disturbance to fish species to occur associated with this (OSPAR, 2012).

213. In addition to potential noise impacts from cable installation activity, there will be an increase in the number of vessels transiting the area associated with construction works. This could also result in increased underwater noise levels and disturbance to fish species. In the context of this assessment, it should be noted that the maximum number of vessels on site at any one time during construction is estimated to be 57 vessels and that a number of existing, busy shipping lanes pass in the proximity of the Norfolk Vanguard site. Fish and shellfish species are therefore expected to be habituated to vessel noise to some extent (Chapter 15 Shipping and Navigation).

214. The limited underwater noise modelling specific to fish receptors that has been carried to date in respect of cable laying activities and vessel noise, suggests that behavioural impacts on fish species would be expected to occur in localised areas in the immediate proximity of the activities/vessels (i.e. from tens to few hundred

metres) (MORL, 2012; Statoil, 2014). Considering the limited areas potentially affected and the temporary nature of the construction phase (up to 2 years), the magnitude of the impact is considered to be low.

215. Taking account of the comparatively wide distribution ranges of fish and shellfish species in the context of the small areas potentially affected, their sensitivity is considered to be low, resulting in an impact of **minor adverse** significance.

11.7.4.4.2 Two phase approach

216. The principal difference between the two phase and single phase approach relates to the overall period of time over which works may be undertaken. Under the two phase option the indicative construction window would be up to 4 years. This scenario would mean underwater noise from construction activities (i.e. vessel noise, cable installation) would be produced in two consecutive separate periods. However, the areas affected by noise and the overall duration of disturbance would remain the same. Therefore, both the sensitivity of the receptors and the magnitude of the impact would also be expected to remain the same. For this reason, it is not considered that a two phase approach would materially change the assessment of significance to fish and shellfish receptors compared with a single phase approach.

11.7.4.5 Impact 5: Underwater noise from UXO clearance

217. Prior to construction, a detailed underwater unexploded ordnance (UXO) survey will be undertaken. Any UXO identified would preferably be avoided or removed from the seabed and disposed of onshore in a designated area. However, where it is deemed unsafe to retrieve the UXO from the seafloor a controlled detonation may be required.

218. As outlined in Appendix 5.2 (Ordtek UXO Review), a range of different types of UXO may be found in areas relevant to Norfolk Vanguard. These are outlined in Table 11.21. The Net Explosive Quantity (NEQ) of explosive material in the device has been corrected, depending on the type of explosive material, to an equivalent quantity of TNT (Appendix 5.4: Underwater noise from UXO).

Table 11.21 UXO devices potentially present at Norfolk Vanguard

UXO Item	NEQ	TNT eq.
250lb HE Bomb (Amatol / TNT)	55kg	55kg
500lb HE Bomb (Amatol / TNT)	120kg	120kg
1000lb HE Bomb (Amatol / TNT)	250kg	250kg
British MK14 Buoyant mine	227kg	261kg
British A Mk6 Ground mine	430kg	525kg
German E series buoyant mine (Wet Gun Cotton/TNT – worst case)	150kg	150kg
German LMB (GC) Ground mine (Hexanite)	700kg	770kg

219. There are limited acoustic measurements for underwater explosions and there can be large differences in the noise levels, depending on the charge size, water depth, as well as bathymetry and seabed sediments at the site, which can influence noise propagation (von Benda-Beckmann *et al*., 2015).

220. In-water explosions produce a spherical shock wave that travels at speeds greater than the speed of sound in water. A large oscillating gas bubble is also produced that radiates sound (Popper *et al*., 2014).

221. Whilst it is well established that explosions can result in potential mortality or injury to fish species at close range, there is no data on the effects of explosions on fish hearing (e.g. TTS) or behaviour currently available. Existing information suggests that there may be temporary or partial loss of hearing at high sound levels, especially in fish where the swim bladder enhances sound pressure detection. In the case of behavioural impacts, it is considered that startle responses are likely to occur if the received signal is of sufficient magnitude. Such responses last less than a second and do not necessarily result in significant changes in subsequent behaviour (Popper *et al*., 2014).

222. In order to inform this assessment, estimated ranges of impact associated with UXO detonations for different charge weights have been calculated to provide an indication of the ranges at which mortality/potential injury may occur on fish species (Appendix 5.4: Underwater Noise from UXO). As outlined in Popper *et al.,* (2014) fish species are considered to be at risk of mortality or potential mortal injury at a peak SPL of 229dB re 1µPa. The ranges at which this noise level could occur are provided in Table 11.22.

223. In the context of this assessment, it should be noted that the noise produced by the detonation of explosives is affected by a number of different elements, only one of which, the charge weight, can easily be factored into a calculation. Many other elements relating to its situation (e.g. its design, composition, age, position, orientation, whether it is covered by sediment) and exactly how they will affect the sound produced by detonation are unknown and cannot be directly considered in an assessment. This leads to a high degree of uncertainty in the estimation of the source noise level (i.e. the noise level at the position of the UXO). A worst case estimation has therefore been used for calculations, assuming that the UXO to be detonated is not buried, degraded or subject to any other significant attenuation. The consequence of this is that the noise levels produced, particularly by the larger explosives under consideration, are likely to be over-estimated as they are likely to be covered by sediment and degraded (Appendix 5.4: Underwater Noise from UXO).

Table 11.22 Calculated mortal and potential injury impact ranges (m) for any fish species (Source: Appendix 5.4: Underwater Noise from UXO)

	Charge Weight						
	55kg	120kg	150kg	250kg	261kg	525kg	770kg
Range (m)	390	500	530	570	580	800	910

224. The risk of recoverable injury (including PTS), TTS and behavioural impacts are presented qualitatively in line with Popper *et al.* (2014) approach in Table 11.23. It should be noted that the risks outlined in Table 11.23 are based on small charges, such as those used to dismantle in-water structures. A greater risk should therefore be assumed for larger charges (Appendix 5.4: Underwater Noise from UXO).

Table 11.23 Qualitative risk of recoverable injury, TTS and behavioural impact for fish species groups (Popper *et al.*, 2014)

Fish species group	Recoverable Injury	TTS	Behaviour
Fish (no swim bladder)	(N) High (I) Low (F) Low	(N) High (I) Moderate (L) Low	(N) High (I) Moderate (F) Low
Fish (swim bladder not involved in hearing)	(N) High (I) High (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) High (F) Low
Fish (swim bladder involved in hearing)	(N) High (I) High (F) Low	(N) High (I) High (F) Low	(N) High (I) High (F) Low
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F). (N), (I) and (F) are equivalent to tens, hundreds and thousands of metres respectively.			

225. As it is apparent from the above, where the detonation of UXO within the offshore project area is required, this may result in injury and disturbance to fish species in the vicinity of the detonation. Physical injury / trauma would occur in close proximity to the detonation, with TTS and behavioural effects occurring at greater distance. Given the short and intermittent nature of this activity (limited to instances when detonation of UXO is required) and the fact that for the most part any effects would be limited to the vicinity of the area where the detonation takes place, the magnitude of the effect is considered to be low.

226. Taking account of the severity of the impact particularly at close range, but acknowledging that impacts would occur at individual rather than at population levels, fish species are considered receptors of medium sensitivity.

227. This, in combination with the low magnitude of the effect results in an impact of **minor adverse** significance.

11.7.5 Potential Impacts during Operation

228. The potential impacts of Norfolk Vanguard on fish and shellfish receptors during the operational phase are described below, including:

- Permanent loss of habitat;
- Introduction of hard substrate;
- Operational noise; and
- Electromagnetic Fields (EMFs).

229. The assessment has been carried out taking account of the worst case parameters outlined in Table 11.11 and with reference to the worst case layout options at NV East and NV West.

230. Where relevant the magnitude of the impact is described separately for the OWF sites and the offshore export cable as well as for the project as a whole. Note that the assessment of significance provided is always based on the magnitude of impact defined for the project as a whole.

11.7.5.1 Impact 1: permanent loss of seabed habitat

231. The worst case scenario in terms of permanent loss of habitat during the operational phase is presented in Table 11.11. This would be primarily a result of the introduction of foundations associated with turbines, offshore electrical platforms, accommodation platforms, met masts and LiDARs and any required scour around these structures, as well as protection measures introduced for the array, interconnector and export cables.

232. In the OWF sites the worst case total area of habitat loss has been estimated to be 11.6km^2 (Table 11.11). Note that this would account for a very small proportion of the area of the OWF sites (2.0%).

233. Similarly, in the case of the export cable the area of seabed loss would be very small, being limited to areas where cable protection measures may be required (0.16km^2), particularly those associated with cable crossings.

234. Loss of habitat would be permanent throughout the expected design life of approximately 30 years. However, given the relatively small area of seabed potentially lost in the OWF sites and the fact that this area would be scattered in smaller sections across the sites (i.e. being limited to localised individual areas where project infrastructure is located) the effect is considered to be of low magnitude**.** In the particular case of the offshore export cable, given the comparatively smaller footprint of the habitat loss the magnitude of the impact is considered to be

negligible. Considering the project as a whole the magnitude of the impact would be low.

235. The fish and shellfish species likely present in areas relevant to the project use comparatively large areas for spawning, as nursery grounds and for foraging, and for the most have wide distribution ranges; all of which may be spatially and temporally variable. Further, as indicated in Chapter 10 Benthic and Intertidal Ecology, significant impacts on the benthos associated with permanent loss of habitat are not expected (impacts assessed as of minor adverse significance in Chapter 10 Benthic and Intertidal Ecology). Therefore, in general terms, impacts as a result of habitat loss are expected to be minimal and fish and shellfish species are considered receptors of low sensitivity. In combination with the low magnitude of effect assessed for the project, the impact of permanent loss of habitat is considered to be of **minor adverse** significance.

236. It is recognised, however that species that are highly dependent on the presence of specific seabed substrates during sensitive periods of their life cycle such as sandeels and herring may have increased susceptibility to the potential impact of habitat loss. Impacts on these species are therefore assessed separately below.

11.7.5.1.1 Sandeels

237. Sandeels are dependent on the presence of an adequate sandy substrate in which to burrow, have a high level of site fidelity and little ability as re-colonisers (Jensen *et al*., 2011). Further, they are demersal spawners which lay their eggs on the seabed. There could be therefore potential for the permanent loss of seabed habitat associated with the project, which would result in a loss of habitat to sandeels, including a loss of spawning habitat.

238. As shown in Figure 11.21, Particle Size Analysis (PSA) data indicates the presence of preferred sandeel habitat (primarily sub-prime habitat) throughout the majority of the offshore project area, as well as the wider former East Anglia Zone. Sandeels have been recorded within the study area by the IBTS, particularly in ICES rectangle 34F3 where the eastern section of NV East is located (see section 11.6.2) and during site specific surveys (Appendix 11.1). Therefore sandeels are anticipated to be present in the offshore project area.

239. Even though sandeels are expected to be present, analysis of IBTS data for the wider North Sea (Figure 11.16 to Figure 11.19), the distribution of high intensity spawning/nursery grounds for this species (Figure 11.10) and of sandeel fishing density in the wider North Sea (Figure 11.22) suggest that the offshore project area is of comparatively low importance in the context of the Sandeel Assessment Area

1r. Similarly, the findings of the sandeel habitat mapping exercise presented in Jensen *et al.* (2011) indicate that key areas to sandeels are located to the north and east of the project with the level of overlap between known sandeel grounds and the project being very small and limited to a discrete small section at the edge of the eastern boundary of NV East. When compared to the total sandeel grounds within Sandeel Assessment Area 1r, the overlap is minimal in its extent (see Figure 11.20).

240. Taking the above into account sandeels are considered receptors of medium sensitivity.

241. In light of the low magnitude of the impact assessed for the project and the medium sensitivity of the receptor, the impact of permanent loss of seabed is assessed to be of **minor adverse** significance.

11.7.5.1.2 Herring

242. Herring are demersal spawners requiring the presence of a coarse substrate on which to deposit their eggs. There could be therefore potential for the loss of seabed habitat associated with the project to result in a loss of spawning grounds to this species.

243. Whilst herring are likely to be found in the study area at times (as suggested by landings data, section 11.6.3 and from records from the IBTS, Figure 11.12) there is no evidence to suggest that they use areas within the offshore project area as spawning grounds. As indicated by the results of the IHLS (Figure 11.13 to Figure 11.15) and the distribution of spawning grounds described in Coull *et al*. (1998) (Figure 11.7) the closest known spawning area of herring is located to the west of the offshore project area close to shore. The closest large scale spawning ground is located towards the English Channel (Downs herring) rather than in the OWF sites or the export cable corridor. Herring is therefore considered a receptor of low sensitivity.

244. Taking the low magnitude of the effect assessed for the project and low sensitivity of the receptor the impact of permanent loss of habitat is assessed to be of **minor adverse** significance.

11.7.5.2 Impact 2: Introduction of hard substrate

245. The introduction of subsurface infrastructure associated with Norfolk Vanguard has the potential to alter the structure of benthic habitats and associated faunal assemblages. All project infrastructure that has a sub sea-surface element would represent a potential substrate for colonisation by marine fauna and flora, including species that may not currently be found within the existing environment.

246. The seabed across the offshore cable corridor, NV West and NV East is relatively homogeneous being characterised predominantly by medium sand (Chapter 8 Marine Physical Processes). The introduction of hard substrate associated with Norfolk Vanguard would therefore increase habitat heterogeneity through the introduction of hard structures in an area predominantly characterised by soft substrate habitat.

247. Hard substrates introduced as part of the project would include turbines, foundations and associated scour protection as well as cable protection. In light of the 3-dimensional nature of much of these structures, the total volume of hard substrate to be introduced is not easy to predict. Under the worst case scenario, however, the area of introduced substrate would be in excess of the permanent loss of area estimated for the project (see section 11.7.5.1).

248. Any hard substrate associated with the installation of Norfolk Vanguard would occupy discrete areas only (i.e. around foundations) and would not be continuous along large lengths of either array or offshore export cables. Taking this into account and the relatively small overall area occupied by the infrastructure associated with the project, the magnitude of the effect is considered to be low in respect of the OWF sites (where the majority of hard substrate will be introduced). In the particular case of the offshore export cable, given the small areas where cable protection is anticipated to be used the magnitude of the impact is considered negligible, with the magnitude of the project as a whole (OWF sites and offshore export cable corridor) assessed as low. The potential for marine subsea structures, whether man-made or natural, to attract and concentrate fish is well documented (Sayer *et al.,* 2005; Bohnsack, 1989; Bohnsack and Sutherland, 1985; Jørgensen *et al.,* 2002). As such, the expected increase in diversity and productivity of seabed communities may have an impact on fish, resulting in either attraction, increased productivity or changes in species composition (Hoffman *et al*., 2000).

249. The Horns Rev offshore wind farm monitoring follow-up report published in 2011 (Stenberg *et al.,* 2011) examined the changes in the fish community seven years after construction of the project. This report suggests that the introduction of hard substrate has resulted in minor changes in the fish community and species diversity. Fish community changes were observed due to changes in densities of the most commonly occurring fish, whiting and dab. This however reflected the general trend of these fish populations in the North Sea.

250. Similarly, a review of the short term ecological effects of the offshore wind farm Egmond aan Zee (OWEZ) in the Netherlands, based on two year post construction monitoring (Lindeboom *et al.,* 2011) found minor effects upon fish assemblages, especially near the monopiles. It was suggested that species such as cod may find

shelter within the wind farm. A similar study conducted in the Belgian part of the North Sea (Bligh Bank wind farm; 55 monopile foundations) found that there was a decrease in overall demersal fish densities within the windfarm compared to control sites. However, for a number of commercially important species (turbot, sole and plaice), higher densities/increases in length distribution were observed (Vandendriessche *et al.,* 2012). It was not possible to determine whether this was attributable to a refuge effect (commercial fishing is excluded from Belgian wind farms), changes in epibenthic fauna (e.g. prey), substrate composition, or any combination of these variables.

251. Monitoring studies carried out at the Lillgrund wind farm in Sweden on the abundance and distribution patterns of benthic fish communities (Bergström *et al*., 2013) found no large-scale effects on fish diversity and abundance after establishment of the wind farm when compared to the development in 2 reference areas. Changes in some species and in community composition were observed over time but occurred in parallel in at least one reference area, indicating that fish communities in the wind farm area were mainly driven by the same environmental factors as those in surrounding areas. Changes at smaller spatial scales were noted, particularly an increase in all studied piscivores (cod, eel, shorthorn sculpin), as well as the reef-associated goldsinny wrasse, which were all observed close to the foundations in the first years of operation.

252. Similarly, the results of pre-construction and post construction monitoring surveys in North Hoyle and Barrow offshore wind farms in the UK suggest the abundance of commercial fish species has remained broadly comparable and in line with long term trends in the regional area (Cefas, 2010).

253. Crustaceans would be expected to exhibit the greatest affinity to scour protection material and foundation bases through the expansion of their natural habitats (Linley *et al.,* 2007). There may be therefore potential for increases of benthic species including crabs and lobsters as a result of colonisation of subsurface structures by subtidal sessile species on which they feed (Linley *et al.,* 2007). Post construction monitoring surveys at the Horns Rev 1 offshore wind farm noted that the hard substrates were used as a hatchery or nursery ground for several species, and was particularly successful for edible crab. They concluded that larvae and juveniles rapidly invade the hard substrates from the breeding areas (BioConsult, 2006).

254. As suggested by the results of the post construction monitoring surveys cited above, any changes in the community structure and abundance of fish and shellfish species within Norfolk Vanguard would be expected to be small and for the most limited to the immediate vicinity of the hard substrate introduced. As noted in Chapter 10 Benthic and Intertidal Ecology, there is likely to be only a small interaction between

the remaining available sea bed and the introduced hard substrate and any interactions would be highly localised (impact of introduction of hard substrate on benthic communities assessed as of minor adverse significance in Chapter 10 Benthic and Intertidal Ecology).

255. In light of the above the sensitivity of fish and shellfish receptors is considered to be low. Taking the low magnitude of the effect assessed for the project and the low sensitivity of the receptors, the impact is considered to be of **minor adverse** significance.

11.7.5.3 Impact 3: Underwater noise during operation

256. Sources of operational noise would include wind turbine vibration, the contact of waves with offshore structures and noise associated with increased vessel movement. This would result in increase in underwater noise in respect of the existing baseline (i.e. pre-construction).

257. Noise monitoring studies in the UK have shown noise levels from operational turbines from North Hoyle, Scroby Sands, Kentish Flats and Barrow windfarms to be only marginally above ambient noise levels (Cefas, 2010; Nedwell *et al.,* 2007; Edwards *et al.,* 2007). Operational noise measurements undertaken in Germany have also found that noise levels were similar to background ambient noise levels (Betke *et al*., 2004).

258. Noise from the operation of wind turbines would be present for the design life of the project (expected to be approximately 30 years) and would contribute to the ambient noise in the region. As suggested above, however this has been shown to be low, only slightly elevated above background ambient noise levels.

259. O&M vessels servicing the project would also generate noise. Note that at worst, a maximum of 440 vessel round trips are expected to occur each year (average of 1-2/day) during the operational phase. This would be very small in the context of the current levels of vessel traffic in the area which is located in the Deepwater Shipping Route (Chapter 15 Shipping and Navigation).

260. Taking the small increase above background noise levels expected during operation and the localised nature of operational noise the magnitude of the impact for the project is considered to be low.

261. A review of monitoring data from operational UK offshore wind farms by Cefas (2009) found no evidence from post-construction fish surveys that operational noise resulted in significant impacts on fish populations, either in terms of changes to species composition or reductions in abundance. Monitoring during the operational phase at the Horns Rev 1 offshore windfarm revealed that colonisation of scour

protection at the base of wind turbine foundations by edible crab had been rapid with up to 1,900 individuals recorded per m^2. As colonisation was rapid and prolific these results were interpreted to indicate that operational noise had no impact on shellfish populations (Leonhard *et al.,* 2006).

262. In view of the above, the sensitivity of fish and shellfish species to operational noise is considered to be low. This, combined with the low magnitude of the effect, would result in and impact of **minor adverse** significance.

11.7.5.4 Impact 4: Electromagnetic Fields (EMFs)

263. As stated in the section describing embedded mitigation (section 11.7.1), cables would be buried where possible to a minimum depth of 1m. Where substrate conditions prevent burial, and at cable or pipeline crossings, cable protection would be deployed.

264. The worst case scenario in respect of EMF related impacts would result from the minimum cable burial depth (1m) and installation of the maximum cable lengths and the highest rating. This would be 600km of 66kV AC array cables, 150km of interconnector cables and 400km of 320kV HVDC export cables.

265. Normandeau *et al.,* (2011) modelled expected magnetic fields using design characteristics taken from a range of undersea cable projects. For eight of the ten AC cables modelled it was found that the intensity of the magnetic field (B) was approximately a direct function of voltage (ranging from 33kV to 345kV) although separation between the cables and burial depth also influenced field strengths. Similarly, the modelling carried out for nine DC cables also found that the B field was a function of voltage (ranging from 75 to 500kV) and cable configuration. For both AC and DC cables, the predicted B fields were strongest directly over the cables and decreased rapidly with vertical and horizontal distance from the cables (Table 11.24 and Table 11.25).

Table 11.24 Averaged magnetic field strength values from AC cables buried 1m (Normandeau *et al*., 2011)

Distance (m) above seabed	Magnetic Fields Strength (µT) Horizontal distance (m) from cable		
	0m	4m	10m
0	7.85	1.47	0.22
5	0.35	0.29	0.14
10	0.13	0.12	0.08

Table 11.25 Averaged magnetic field strength values from DC cables buried 1m (Normandeau *et al*., 2011)

Distance (m) above seabed	Magnetic Fields Strength (µT) Horizontal distance (m) from cable		
	0m	4m	10m
0	78.27	5.97	1.02
5	2.73	1.92	0.75
10	0.83	0.74	0.46

266. The areas affected by EMFs generated by the worst case scenario are therefore expected to be small, being limited to the area of the OWF sites and the offshore cable corridor and restricted to the immediate vicinity of the cables (i.e. within metres). In addition, EMFs are expected to attenuate rapidly in both horizontal and vertical plains with distance from the source. The magnitude of the effect is therefore considered to be low. This is considered to be the case in respect of cables within the OWF sites, the offshore export cables and for the project as a whole.

267. With regards to receptor sensitivity, a number of organisms in the marine environment are known either to be sensitive to electromagnetic fields or have the potential to detect them (Gill and Taylor, 2001; Gill *et al*., 2005). These organisms can be categorised into two groups based on their mode of magnetic field detection, which may be induced electric field detection or direct magnetic field detection.

268. The first group are those species that are electro-receptive, the majority of which are elasmobranchs (sharks, skates and rays), although it also includes holocephalans (chimaeras, e.g. ratfish) and agnathans (i.e. lampreys). These can detect the presence of a magnetic field either indirectly by detection of the electrical field induced by the movement of water through a magnetic field or directly by their own movement through that field. The magnetic field could be the Earth’s geomagnetic field or a magnetic field produced by a power cable. In natural scenarios, induction of the electric field usually results from organisms positioning themselves in tidal currents and animals may time activities such as foraging or migration by detecting diurnal cues resulting from varying tidal flows.

269. The second group are believed to use magnetic particles (magnetite) within their own tissues in magnetic field detection (Kirshvink, 1997). Whilst the exact mechanism is still not understood, it is generally believed that they are able to detect magnetic cues such as the Earth’s geomagnetic field to orientate during migration.

270. With reference to the area where Norfolk Vanguard is located, relevant groups are teleosts (bony fish, i.e. salmon and eel), crustaceans (lobsters, crabs, prawns and shrimps) and molluscs (snails, bivalves and cephalopods).

271. The sensitivity of the fish and shellfish receptors potentially found in the OWF sites and the export cable corridor area, for which there is evidence of a response to electric or magnetic fields, is given in the following sections together with an assessment of the potential impacts arising from the proposed worst case cabling,

11.7.5.4.1 Elasmobranchs

272. Elasmobranchs are the species group considered to be the most electro sensitive. These species naturally detect bioelectric emissions from prey, conspecifics and potential predators and competitors (Gill *et al.,* 2005). They are also known to detect magnetic fields.

273. The results of various laboratory and field experiments carried out using AC cables of the type used by the offshore renewable energy industry, suggest that that the EMFs emitted are within the range of detection by electro sensitive species such as rays and dogfish (Gill and Taylor, 2001; Gill *et al*., 2005; Gill *et al*., 2009; CMACS, 2003; COWRIE, 2009).

274. It has been hypothesised that elasmobranchs may be confused by anthropogenic electric field sources that lie within similar ranges to natural bioelectric fields. Laboratory behavioural studies have demonstrated both AC and DC artificial electric fields stimulating feeding responses in elasmobranchs (Kalmijn 1982; Tricas & Sisneros, 2004; Kimber *et al.,* 2011). Studies with lesser spotted dogfish suggest that despite the ability to distinguish certain artificial E fields (strong versus weak; DC versus AC), sharks seemed either unable to distinguish, or showed no preference between, anthropogenic (dipole) and natural (live crab) DC E fields of similar strengths (Kimber *et al.,* 2011). Experiments by Gill *et al*. (2009) provided the first evidence of electrically sensitive fish response to AC EMF emissions from sub-sea, electricity cables of the type used by the offshore renewable energy industry. This research found lesser spotted dogfish were more likely to be found within the zone of EMF emissions, and some thornback rays showed increased movement around the cable when the cable was switched on. Responses were unpredictable however, did not always occur, and appeared to be species dependent and individual specific.

275. Information gathered as part of the monitoring programme at Burbo Bank OWF suggested that certain elasmobranch species feed inside the wind farm and demonstrated that they are not excluded during periods of low power generation (Cefas, 2009). Monitoring at Kentish Flats found an increase in thornback rays,

smoothhounds and other elasmobranchs during post-construction surveys in comparison to surveys before construction. There appeared to be no discernible difference however, between the data for the windfarm and reference areas in terms of changes to population structure and it was concluded that the population increase observed was unlikely to be related to the operation of the windfarm (Cefas 2009).

276. In line with the above, the following was stated in respect of EMF effects in the review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms published in 2014 (MMO, 2014):

277. “From the results of post-consent monitoring conducted to date, there is no evidence to suggest that EMFs pose a significant threat to elasmobranchs at the site or population level, and little uncertainty remains. Targeted research using high tech equipment and experimental precision has been unable to ascertain information beyond that of fish being able to detect EMFs and at what levels they become attracted or abhorrent to them. EMFs emitted from standard industry cables for OWFs are unlikely to be repellent to elasmobranchs beyond a few metres from the cable if buried to sufficient depth. It is likely that the subtler effects of EMF, including attraction of elasmobranchs, inquisitiveness and feeding response to low level EMFs, may occur. The Burbo Bank OWF post-consent monitoring undertook EMF specific surveys including stomach analysis of common elasmobranch species. Fish caught at the cable site (and hence subject to EMFs) were well fed. No deleterious effects were recorded to fish populations, at least when this effect occurs in association with the probable increased feeding opportunities reported as a result of increased habitat heterogeneity".

278. Taking the above into account, it is considered that EMF-related effects would, at worst, only result in temporary, short term behavioural reactions rather than cause a barrier to migration or result in long term impacts upon feeding or confusion in elasmobranch species. In view of this and the likely presence of elasmobranch species in the OWF sites and along the offshore cable corridor, elasmobranchs are considered receptors of medium sensitivity. In combination with the low magnitude of the effect assessed for the project the impact of EMFs on elasmobranch species is considered to be of **minor adverse** significance**.**

11.7.5.4.2 Lamprey

279. Lampreys, like elasmobranchs, possess electroreceptors that are sensitive to weak, low-frequency electric fields (Bodznick and Northcutt, 1981; Bodznick and Preston, 1983). Whilst responses to electric fields have been reported in these species, information on the use that they make of the electric sense is limited. It is likely

however, that they use it in a similar way as elasmobranchs to detect prey, predators or conspecifics and potentially for orientation or navigation (Normadeau *et al.,* 2011). Spawning of lampreys occurs in rivers. Therefore, lampreys are only expected to be sporadically present in the vicinity of Norfolk Vanguard during the marine migration phase and their sensitivity to EMFs is considered to be low. This combined with the low magnitude of effect assessed for the project results in an impact of **minor adverse** significance.

11.7.5.4.3 Salmon and Sea trout

280. Any potential impacts on movement and behaviour in salmonids would be closely linked to the proximity of the fish to the EMF source. Gill and Bartlett (2010) suggest that any impact associated with EMFs on the migration of salmon and sea trout would be dependent on the depth of water and the proximity of home rivers to development sites. During the later stages of marine migration, salmon and sea trout rely on their olfactory system to find and identify their natal river. During these stages, they are likely to be migrating in the mid to upper layers of the water column.

281. As indicated in Table 11.10 there are no salmon rivers in the vicinity of the offshore project area and the potential interaction of salmon with the project would only be expected to occur on an occasional basis during marine migration/feeding. In the case of sea trout, there may be increased potential for the species to transit the offshore project area, particularly areas relevant to export cable corridor, as sea trout are known to feed off the Norfolk coast (Table 11.10).

282. It should be noted, however, that Swedpower (2003) found no measurable impact when subjecting salmon and sea trout to magnetic fields twice the magnitude of the geomagnetic field. Similarly, in a recent study conducted by Marine Scotland Science (Armstrong *et al*., 2016) where the effects on the behaviour of captive Atlantic salmon of mains frequency (50Hz) magnetic fields were studied, no evidence of unusual behaviour was found associated with magnetic fields up to 95µT. Further, Atlantic salmon migration in and out of the Baltic Sea over a number of operational subsea HVDC cables has been observed to continue apparently unaffected by the EMFs produced by the cables (Walker, 2001).

283. Taking the above into account, Atlantic salmon and sea trout are considered receptors of low sensitivity. This together with the low magnitude of the impact assessed for the project results in an impact of **minor adverse** significance**.**

11.7.5.4.4 European Eel

284. As described in Table 11.10 European eel may transit both the offshore cable corridor and the OWF sites.

285. Various studies have been carried out in relation to the migration of eels and the potential effect of EMFs derived from offshore wind farm cables. Experiments undertaken at the operational wind farm of Nysted detected barrier effects, however correlation analysis between catch data and data on power production showed no indication that the observed effects were attributable to EMFs. Furthermore, mark and recapture experiments showed that eels did cross the offshore export cable (Hvidt *et al.,* 2005). Similarly, a recent study carried out by Marine Scotland Science (Orpwood *et al.,* 2015) where European eels were exposed to an AC magnetic field of 9.6µT found no evidence of a difference in movement, nor observations of startle or other obvious behavioural changes associated with the magnetic fields.

286. Taking the above into account, European eel is considered a receptor of low sensitivity. This, in combination with the low magnitude of effect assessed for the project would result in an impact of **minor adverse** significance.

11.7.5.4.5 Other Fish Species

287. Further to the species mentioned above, there is some evidence of a response to EMFs in other fish species, such as cod and plaice (Gill *et al.,* 2005).

288. As suggested in the assessments of operational noise and introduction of hard substrate sections (section 11.7.5.2 and 11.7.5.3), the results of monitoring programmes carried out in operational windfarms to date do not suggest that significant changes in the fish assemblage have occurred during the operational phase. It has been suggested that the presence of the foundations and scour protection and potential changes in the fisheries related to offshore windfarm development would have the most impact upon fish species (Lindeboom *et al*., 2011) and that noise from the wind turbines and EMFs from cabling do not seem to have a major impact on fish and other mobile organisms attracted to the hard bottom substrates for foraging, shelter and protection (Leonhard and Pedersen, 2006). In line with this, research carried out at the Nysted offshore windfarm in Denmark that focused on detecting and assessing possible impacts of EMFs on fish during power transmission (Hvidt *et al.,* 2005) found no differences in the fish community composition after the windfarm became operational. In light of the above, other fish species for which there is some evidence of a response to EMFs are considered

receptors of low sensitivity. This in combination with the low magnitude of effect assessed for the project results in an impact of **minor adverse** significance

11.7.5.4.6 Shellfish

289. Research on the ability of marine invertebrates to detect EMF has been limited to date. Although there is no direct evidence of effects to invertebrates from undersea cable EMF (Normandeau *et al.,* 2011), the ability to detect magnetic fields has been studied for some species and there is evidence in some of a response to magnetic fields, including molluscs and crustaceans.

290. Crustacea, including lobster and crabs, have been shown to demonstrate a response to B fields, with the spiny lobster *Panulirus argus* shown to use a magnetic map for navigation (Boles and Lohmann, 2003). However, it is uncertain if other crustaceans including commercially important brown crab and European lobster are able to respond to magnetic fields in this way. Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau *et al*., 2011; Ueno *et al.,* 1986). Indirect evidence from post construction monitoring programmes undertaken in operational wind farms also does not suggest that crustaceans or molluscs have been affected by the presence of submarine power cables.

291. Research undertaken by Bochert and Zettler (2004), where a number of species, including brown shrimp, were exposed to a static magnetic field for several weeks, found no differences in survival between experimental and control animals.

292. The role of the magnetic sense in invertebrates has been hypothesised to function in relation to orientation, navigation and homing, using geomagnetic cues (Cain *et al.,* 2005; Lohmann *et al*., 2007). Research undertaken on the Caribbean spiny lobster (Boles and Lohmann, 2003) suggests that this species derives positional information from the Earth's magnetic field that is used during long distance migration.

293. Based on the research available, the sensitivity of shellfish species to EMFs is considered to be low. Taking the low magnitude of the effect assessed for the project and the receptor sensitivity the impact is considered to be of **minor adverse** significance.

11.7.6 Potential Impacts during Decommissioning

294. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in Chapter 5 Project Description and the detail will be agreed with the relevant authorities at the time of

decommissioning and be subject to separate licencing based on best available information at that time. Offshore, this is likely to include removal of all of the wind turbine components and part of the foundations (those above seabed level). Some or all of the array cables, interconnector cables, and offshore export cables may be removed. Scour and cable protection would likely be left *in situ.*

295. The process for removal of foundations is generally the reverse of the installation process. It should be noted, however, that foundations would be cut and therefore no piling will be required during the decommissioning phase.

296. In respect of cables, general UK practice will be followed, i.e. buried cables will simply be cut at the ends and left in-situ.

297. In light of the above, it is anticipated that types of effect on fish and shellfish receptor would be comparable to those identified for the construction phase, namely:

- Impact 1: Physical Disturbance/Temporary Loss of Habitat;
- Impact 2: Increased SSCs and Sediment Re-deposition;
- Impact 3: Underwater Noise from foundation removal;
- Impact 4: Underwater noise from other decommissioning activities.

298. The sensitivity of receptors during decommissioning is assumed to be the same as given for the construction phase. The magnitude of effect is considered to be no greater and in all probability less than considered for the construction phase. Therefore, it is anticipated that any decommissioning impacts would be no greater, and probably less than those assessed for the construction phase.

299. It is anticipated that decommissioning will be undertaken in the same phased approach as used for construction to allow approximately 30 year design life from commissioning of each phase. Based on previous estimates and experience it is anticipated that decommissioning of each phase would take approximately 1 year.

300. As an alternative to decommissioning, the owners may wish to consider re-powering the wind farm. Should the owners choose to pursue this option, this would be subject to a new application for consent.

11.8 Cumulative Impacts

301. The development activities taken forward for cumulative assessment have been selected on the basis of availability and quality of information and the probability of a cumulative impact occurring, including, where relevant, spatial overlap.

302. The potential impacts taken forward for cumulative assessment are as described above for assessment of the project alone and include the following:

- Construction Phase:
  - Impact 1: Physical disturbance and temporary habitat loss;
  - Impact 2: Increase in SSCs and sediment re-deposition;
  - Impact 3: Underwater noise associated with pile driving during construction;
  - Impact 4: Noise from other construction activities; and
  - Impact 5: Noise from UXO clearance.
- Operation Phase:
  - Impact 1: Permanent loss of seabed habitat;
  - Impact 2: Introduction of hard substrate;
  - Impact 3: Operation noise;
  - Impact 4: EMFs
- Decommissioning:
  - Impact 1: Physical disturbance and temporary habitat loss;
  - Impact 2: Increase in SSCs and sediment re-deposition;
  - Impact 3: Underwater noise associated with removal of foundations; and
  - Impact 4: Noise from other decommissioning activities.

303. Project tier definitions have been identified in the project list (Table 11.26) and follow the approach suggested by Natural England and JNCC for East Anglia Three as follows:

- Tier 1 – Built operational projects;
- Tier 2 – Projects under construction;
- Tier 3 – Consented;
- Tier 4 – Application submitted and not yet determined;
- Tier 5 – In planning (scoped), application not yet submitted; and
- Tier 6 – Identified in strategic plans but not yet in planning.

304. Note that projects in Tier 1 are already operational and therefore are not considered in this assessment as they form part of the existing environment.

Table 11.26 Summary of Projects considered for the Cumulative Impact Assessment in relation to Fish and Shellfish Ecology

Project	Distance from site (km)	Size (MW)	Maximum number of turbines
Norfolk Vanguard	**N/A**	**1,800**	**200**
Tier 2: Under Construction			
Galloper	93	336	56
East Anglia ONE	40	714	102
Hornsea Project One	95	1,200	174
Tier 3: Consented			
East Anglia THREE	0	1,200	172
Doggerbank Teesside A	213	1,200	200
Doggerbank Teesside B	200	1,200	200
Doggerbank Creyke Beck A	184	1,200	200
Doggerbank Creyke Beck B	207	1,200	200
Triton Knoll	101	860	90
Tier 4: Application submitted and not yet determined			
Hornsea Project Three	88	2,400	342
Tier 5: Application not yet submitted			
Norfolk Boreas	30	1,800	200
East Anglia 1 North	38	600-800	TBC
East Anglia TWO	56	400-900	TBC
Thanet Extension	159	340	34
Tier 6: Identified in strategic plans but not yet in planning.			
Hornsea Project Four	112	1,000	TBC
Marine Aggregate Dredging			
Area number	**Distance from site (km)**	**Area number**	**Distance from site (km)**
525	27	507/1-6	94
242/361	31	523	101
401/2	31	507/1-6	101
494	33	447	104
212	34	481	114

Project	Distance from site (km)	Size (MW)	Maximum number of turbines
Area number	**Distance from site (km)**	**Area number**	**Distance from site (km)**
296	35	481/1-2	114
240	39	501	114
513/1-2	39	524	119
254	41	501/1-2	120
228	42	480	121
512	43	439	124
401/2	44	509/1-3	124
511	47	106/400	125
484	60	509/1-3	126
430	63	510/1-2	127
483	66	508	128
491	78	106/400	129
506	81	197	132
490	82	493	135
498	90	514/1-4	137
515/1-2	91		

11.8.1 Construction

11.8.1.1 Impact 1: Physical disturbance and temporary loss of area

305. There could be potential for construction works at other projects to result in additional disturbance and temporary habitat loss to fish and shellfish receptors to that identified for the project alone where construction schedules significantly overlap. Given the distances from the project to other projects and activities (Table 11.26) and considering the localised and temporary nature of impacts associated with physical disturbance and temporary loss of habitat (i.e. limited to the immediate vicinity of construction works), however, the magnitude of the cumulative impact is considered to be low.

306. The fish and shellfish species included for assessment have wide overall distribution ranges (including the extent of spawning and nursery grounds for relevant species). The sensitivity of fish species in general is therefore considered to be low. In the case of species which depend on specific substrates and species or life stages of reduced mobility, considering the potential increased area of their habitat affected and their reduced ability to relocate to other areas, the sensitivity is considered to be medium.

With the above in mind the cumulative impact is considered to be **minor adverse** significance**.**

11.8.1.2 Impact 2: Increased SSCs and sediment re-deposition

307. There may be potential for cumulative increased SSCs and sediment re-deposition impacts to occur on the fish and shellfish receptors relevant to the area of Norfolk Vanguards associated with other projects, provided their construction schedules coincide.

308. As discussed in Chapter 8 Marine Geology, Oceanography and Physical Processes, theoretical seabed level changes of up to 2mm are estimated as a result of cumulative impacts of Norfolk Vanguard cable installation and dredging at nearby aggregate sites. Considering the small cumulative changes in seabed level, the expected rapid dispersion of sediment plumes and the localised nature of sediment re-deposition, the magnitude of the potential cumulative impact is considered to be low.

309. Adult and juvenile fish in general, being mobile, would be expected to redistribute to undisturbed areas within their range and are therefore considered receptors of low sensitivity. In the case of species and life stages of relatively low mobility and those highly dependent on the presence of specific substrates, considering the potential increased area of their habitat affected and their more reduced ability to relocate to other areas, their sensitivity is considered to be medium. As a result the impact of increased SSCs and sediment re-deposition is predicted to be of **minor adverse** significance.

11.8.1.3 Impact 3: underwater noise from pile driving

310. There is potential for piling at Norfolk Vanguard and other wind farm projects to result in cumulative impacts on fish species.

311. The potential cumulative impact would be the result of either spatial or temporal effects resulting from concurrent or sequential piling at different offshore wind farms, or a combination of both. Of particular concern in this regard is the potential for cumulative behavioural impacts to occur on species which use the area for spawning, however consideration has also been given to other fish species.

312. Species with spawning grounds in the area relevant to Norfolk Vanguard include:

- Sole;
- Plaice;
- Cod;
- Sandeels
- Whiting

- Lemon sole;
- Mackerel;
- Sprat
- Thornback ray (as inferred from the location of nursery areas); and
- Herring.

313. It should be noted that in the particular case of herring, there are not spawning grounds in the offshore project area. The closest known spawning grounds to the OWF sites are located to the south towards the English Channel (Downs herring). As indicated in section 11.7.4.3, based on the distribution of known spawning grounds and the results of the IHLS, there is little potential for noise associated with Norfolk Vanguard to affect the Downs herring during spawning (Figure 11.31), and therefore little potential for the project to contribute to any cumulative impact on this stock. Similarly, in the case of sandeels, the project overlaps with low intensity spawning grounds for this species with high intensity spawning areas located to the north in the Dogger Bank area. As such, the potential for the project to significantly contribute to the cumulative impact is limited. Recognising the increased potential areas affected by piling noise when considering other projects (particularly those south of the project and therefore closer to the spawning grounds of the Downs stock in the case of herring and those in the Dogger Bank area in the case of sandeels) and considering their seabed habitat specificity, herring and sandeels are considered of medium sensitivity.

314. The remaining species with known spawning grounds in the area have very wide spawning grounds in the context of the relatively small areas over which piling may have an effect. Further, for the most part, areas affected by noise from Norfolk Vanguard are considered of low spawning intensity. The remaining fish species with spawning grounds in the area are therefore considered of low sensitivity.

315. With regards to other fish species present in the area, given the extent of their distribution ranges and the areas used for foraging and as nursery grounds they are also considered receptors of low sensitivity.

316. Taking account of the increased spatial effect (if construction occurs concurrently) or temporal (if construction occurs sequentially) associated with piling in other wind farm projects in addition to Norfolk Vanguard, but recognising the intermittent and short term nature of piling, the magnitude of the potential impact is considered to be low.

317. In this context it is important to note that active piling will only occur over a small percentage of the overall construction period of offshore wind farm projects.

Therefore, it is unlikely that piling will occur concurrently at a significant number of offshore wind farm projects.

318. In view of the above, the cumulative impact of construction noise from piling on fish species is considered of **minor adverse** significance.

11.8.1.4 Impact 4: Noise from other construction activities

319. As described in section 11.7.4.4, potential disturbance to fish and shellfish species associated with construction activities other than piling (i.e. vessel transit and cable laying) would occur over very small areas (i.e. tens to few hundred meters).

320. Whilst the potential for additive disturbance to occur as a result of construction activities in other wind farms, either temporally (where construction is sequential) or spatially (where construction occurs concurrently) is recognised, given the small areas affected and the distance between the projects considered in the assessment and Norfolk Vanguard (Table 11.26), the magnitude of the cumulative impact is considered to be low.

321. Taking account of the comparatively wide distribution ranges of fish and shellfish species in the context of the small areas potentially affected (including the extent of the spawning and nursery grounds of relevant species), the sensitivity of fish and shellfish receptors is considered to be low. This results in an impact of **minor adverse** significance**.**

11.8.1.5 Impact 5: Noise from UXO clearance

322. As described for assessment of noise from UXO removal for the project alone (section 11.7.4.5), the detonation of UXO associated with other offshore wind farm developments, would also result in injury and disturbance to fish species in the vicinity of the detonation. Physical injury / trauma would occur in close proximity to the detonation with TTS and behavioural effects occurring at greater distance.

323. Whilst it is recognised that the number of UXO detonations required will increase (considering the other projects included for cumulative assessment), UXO clearance will still be an activity short term and intermittent in nature (only occurring where UXO cannot be removed by other means). Considering this together with the fact that for the most part any effects on fish and shellfish receptors would be limited to the vicinity of the area where the detonation takes place, the magnitude of the effect is considered to be low.

324. Taking account of the severity of the impact particularly at close range, but acknowledging that impacts would occur at individual rather than at population level, fish species are considered receptors of medium sensitivity.

325. This, in combination with the low magnitude of the effect results in an impact of **minor adverse** significance.

11.8.2 Operation Phase:

11.8.2.1 Impact 1: Permanent loss of seabed habitat

326. There is potential for the introduction of infrastructure associated with Norfolk Vanguard together with that associated with other wind farm projects, to result in cumulative impacts on fish and shellfish species, in terms of loss of seabed habitat.

327. It should be noted, however, that the loss of seabed habitat would occur in a scattered manner, around localised sections of projects (i.e. where cables need protection and around foundations). Taking this into account together with the distance from other projects to Norfolk Vanguard (Table 11.26), the magnitude of the effect is considered to be low.

328. The fish and shellfish species in the regional area use comparatively large areas for spawning, as nursery grounds and for foraging, and for the most have wide distribution ranges. Therefore, in general terms, impacts as a result of habitat loss are expected to be minimal and fish and shellfish species are considered receptors of low sensitivity. In the case of sandeels and herring given their dependence on specific substrates and therefore their more limited habitat availability they are considered of medium sensitivity.

329. With the above in mind the cumulative impact of permanent loss of habitat is considered to be of **minor adverse** significance.

11.8.2.2 Impact 2: Introduction of hard substrate

330. Hard substrate introduced as part of the project together with that introduced as a result of other wind farm projects could result in cumulative impacts on fish and shellfish species in terms of changes to the species assemblage.

331. It should be noted, however, that in line with the cumulative loss of seabed habitat assessed above, the introduction of hard substrate would occur in a scattered manner, around localised sections of the projects (i.e. where cable need protection and around foundations). Taking this into account together with the distance from other project to Norfolk Vanguard (Table 11.26), the magnitude of the effect is considered to be low.

332. As previously mentioned (section 11.7.5.2), the results of post construction monitoring surveys undertaken in operational wind farms to date, suggest that any changes in the community structure and abundance of fish and shellfish species associated with introduction of hard substrate would be highly localised, being for

the most part limited to the immediate vicinity foundations. The sensitivity of fish and shellfish species is considered to be low, resulting in a cumulative impact of **minor adverse** significance.

11.8.2.3 Impact 3: Operational noise

333. During the operational phase there may be potential for operational noise from Norfolk Vanguard to add cumulatively to operational noise from other offshore wind farm projects.

334. However, as outlined for assessment of operational noise for the project alone, the increase above background noise levels expected during operation would be very small and localised in nature. With this in mind and taking the distance between Norfolk Vanguard and other projects (Table 11.26), the magnitude of the effect is considered to be low.

335. Monitoring data from operational wind farms does not suggest that operational noise has potential to result in any discernible effect on fish and shellfish species. With this in mind, fish and shellfish species are considered receptors of low sensitivity. This, combined with the low magnitude of the effect, would result in and impact of **minor adverse** significance.

11.8.2.4 Impact 4: EMFs

336. EMFs associated with cables at Norfolk Vanguard and other offshore wind farm projects could result in a cumulative impact on sensitive fish and shellfish species (particularly elasmobranchs).

337. As described for assessment of EMFs for the project alone, however, areas affected by EMFs would be expected to be very small, being limited to the immediate vicinity of array and export cables (i.e. within metres). Taking this into account, together with the distance from other project to Norfolk Vanguard (Table 11.26), the magnitude of the effect is considered to be low.

338. Considering the wide overall extent of the distribution of the fish and shellfish species in the regional area in the context of the small areas affected by EMFs, fish and shellfish species are considered receptors of low sensitivity.

339. In the particular case of elasmboranchs, given their increased ability to detect EMFs compared to other species groups, their sensitivity is considered to be medium. It should be noted, that as described in section 1.7.4.4 for the project alone, EMFs from cables are expected to at worst, result in temporary, short term behavioural reactions rather than cause a barrier to migration or result in long term impacts upon feeding or confusion in elasmbranchs. This would also apply in a cumulative context.

340. The sensitivities identified above (low for fish and shellfish in general and medium for elasmobranchs), in combination with the low magnitude of the effect, results in an impact of **minor adverse** significance**.**

11.8.3 Decommissioning

341. As outlined for the project alone (section 11.7.6), it is anticipated that the types of effect on fish and shellfish receptor during the decommissioning phase would be comparable to those identified for the construction phase, namely:

- Impact 1: Physical Disturbance/Temporary Loss of Habitat;
- Impact 2: Increased SSCs and Sediment Re-deposition;
- Impact 3: Underwater Noise from foundation removal; and
- Impact 4: Underwater noise from other decommissioning activities.

342. The sensitivity of receptors during the decommissioning is therefore assumed to be the same as given for the construction phase. The magnitude of effect is considered to be no greater and in all probability less than considered for the construction phase. Therefore, it is anticipated that any cumulative decommissioning impacts would be no greater, and probably less than those assessed for the construction phase.

11.9 Transboundary Impacts

343. As described within section 11.4.3, the distribution of fish and shellfish species is independent of national geographical boundaries. The impact assessment has therefore been undertaken taking account of the distribution of fish stocks and populations irrespective of political limits. As a result, it is considered that a specific assessment of trans-boundary effects is unnecessary.

11.10 Inter-relationships

344. The assessment of the impacts arising from construction, operation and decommissioning of the project indicates that impacts on receptors addressed in other ES chapters may potentially further contribute to the impacts assessed on fish and shellfish species and vice versa.

345. The principal linkages identified are summarised in Table 11.27. No inter-relationships have been identified where an accumulation of residual impacts on fish and shellfish ecology gives rise to a need for additional mitigation.

Table 11.27 Fish and shellfish ecology inter-relationships

Topic and description	Related Chapter	Where addressed in this Chapter	Rationale
Benthic and Intertidal Ecology	10	Section 11.7.4 and section 11.7.5	The benthic environment provides the habitat and prey species for fish and shellfish ecology. Therefore, impacts on benthic ecology can have subsequent impacts on fish and shellfish.
Commercial Fisheries	14	Section 11.6.3	Impacts on fish and shellfish ecology can have an impact on the fisheries resource.
Marine Mammals	12	Section 11.6.9	Impacts on fish and shellfish ecology can have an impact on the prey resource for marine mammals.
Offshore Ornithology	13	Section 11.6.9	Impacts on fish and shellfish ecology can have an impact on the prey resource for ornithology.

11.11 Interactions

The impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts as a result of that interaction. The worst case impacts assessed within the chapter take these interactions into account and therefore the impact assessments are considered conservative and robust. For clarity the areas of interaction between impacts are presented in Table 11.28.

Table 11.28 Interactions between impacts

Potential interaction between impacts					
Construction					
	1 Physical disturbance and temporary loss of habitat	2 Increased suspended sediment concentrations and sediment re-deposition	3 Underwater noise from piling	4 Underwater noise from other construction activities	5. Underwater noise from UXO
1 Physical disturbance and temporary loss of habitat	-	Yes	No	No	No
2 Increased suspended sediment concentrations and sediment re-deposition	Yes	-	No	No	No
3 Underwater noise from piling	No	No	-	Yes	Yes
4 Underwater noise from other construction activities	No	No	Yes	-	Yes
5. Underwater noise from UXO	No	No	Yes	Yes	-
Operation					
	1 Permanent loss of seabed habitat	2 Introduction of hard substrate	3 Underwater noise during operation	4 EMF	
1 Permanent loss of seabed habitat	-	Yes	No	No	
2 Introduction of hard substrate	Yes	-	No	No	
3 Underwater noise during operation	No	No	-	No	
4 Electromagnetic Fields (EMF)	No	No	No	-	
Decommissioning					
It is anticipated that the decommissioning impacts will be similar in nature to those of construction.					

11.12 Summary

346. A summary of the outcomes of the impact assessment on fish and shellfish receptors is given in Table 11.29. As shown, significant impacts (above minor) have not been identified.

Table 11.29 Potential impacts identified for Fish and Shellfish receptors

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Construction						
Physical disturbance and temporary loss of seabed habitat	Fish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Sandeels	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Herring	Low	Low	Minor adverse	N/A	**Minor adverse**
	Thornback ray	Low	Low	Minor adverse	N/A	**Minor adverse**
	Shellfish	Medium	Low	Minor adverse	N/A	**Minor adverse**
Increased SSCs and sediment re-deposition	Adult and juvenile fish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Sandeels	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Herring	Low	Low	Minor adverse	N/A	**Minor adverse**
	Other species with spawning grounds in the offshore project area	Low	Low	Minor adverse	N/A	**Minor adverse**
	Shellfish	Low	Low	Minor adverse	N/A	**Minor adverse**
Underwater noise from piling (mortality/recoverable injury)	Fish with no swim bladder	Low - general	Negligible	Negligible	N/A	**Negligible**
		Medium -sandeels	Negligible	Minor adverse	N/A	**Minor adverse**
	Fish with swim bladder not involved in hearing	Low -general	Negligible	Negligible	N/A	**Negligible**
		Medium- Gobies	Negligible	Minor adverse	N/A	**Minor adverse**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	Fish with swim bladder involved in hearing	Low	Negligible	Negligible	N/A	**Negligible**
	Eggs and larvae	Medium	Negligible	Minor adverse	N/A	**Minor adverse**
	Shellfish	Medium	Negligible	Minor adverse	N/A	**Minor adverse**
Underwater noise from piling (TTS and behavioural)	Sole, plaice, lemon sole and mackerel	Low	Low	Minor adverse	N/A	**Minor adverse**
	Sandeels	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Sea bass	Low	Low	Minor adverse	N/A	**Minor adverse**
	Cod, whiting and sprat	Low	Low	Minor adverse	N/A	**Minor adverse**
	Herring	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Elasmobranches	Low	Low	Minor adverse	N/A	**Minor adverse**
	Diadromous species	Low	Low	Minor adverse	N/A	**Minor adverse**
Indirect impacts on fish species as a result of behavioural disturbance to prey species associated with construction noise	Piscivorous fish	Low	Low	Minor adverse	N/A	**Minor adverse**
Underwater noise from other construction activities	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Noise from UXO clearance	Fish and shellfish in general	Medium	Low	Minor adverse	N/A	**Minor adverse**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Operation						
Permanent loss of seabed habitat	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Sandeels	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Herring	Low	Low	Minor adverse	N/A	**Minor adverse**
Introduction of hard substrate	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Underwater noise during operation	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
EMFs	Elasmobranchs	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Lamprey	Low	Low	Minor adverse	N/A	**Minor adverse**
	Salmon and sea trout	Low	Low	Minor adverse	N/A	**Minor adverse**
	European eel	Low	Low	Minor adverse	N/A	**Minor adverse**
	Other fish species	Low	Low	Minor adverse	N/A	**Minor adverse**
	Shellfish	Low	Low	Minor adverse	N/A	**Minor adverse**
Decommissioning						
Physical disturbance and temporary loss of habitat	As above for the construction phase and likely less					
Increased SSCs and sediment re-deposition	As above for the construction phase and likely less					
Underwater noise from	As above for the construction phase and likely less					

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
foundation removal						
Underwater noise from other decommissioning activities	As above for the construction phase and likely less					
Cumulative						
Construction						
Physical disturbance and temporary loss of seabed habitat	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Species which depend on specific substrates or species/life stages of limited mobility	Medium	Low	Minor adverse	N/A	**Minor adverse**
Increased SSCs and sediment re-deposition	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Species which depend on specific substrates or species/life stages of limited mobility	Medium	Low	Minor adverse	N/A	**Minor adverse**
Underwater noise from piling (behavioural)	Fish in general (including species with spawning grounds)	Low	Low	Minor adverse	N/A	**Minor adverse**
	Sandeel and herring	Medium	Low	Minor adverse	N/A	**Minor adverse**
Underwater noise from other	Fish and shellfish in	Low	Low	Minor adverse	N/A	**Minor adverse**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
construction activities	general					
Noise from UXO clearance	Fish and shellfish in general	Medium	Low	Minor adverse	N/A	**Minor adverse**
Operation						
Permanent loss of seabed habitat during operation	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Sandeels and herring	Medium	Low	Minor adverse	N/A	**Minor adverse**
Introduction of hard substrate	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Underwater noise during operation	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
EMFs	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Elasmobranchs	Medium	Low	Minor adverse	N/A	**Minor adverse**
Decommissioning						
As above for the construction phase and likely less						
Transboundary						
N/A	N/A					

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